EFFECT OF NITROGEN LEVELS ON YIELD AND QUALITY OF RAINFED MULBERRY IN RELATION TO PERFORMANCE OF SILKWORM WITH DIFFERENT METHODS AND REGIMES OF FEEDING

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF NITROGEN LEVELS ON YIELD AND QUALITY OF RAINFED MUBLERRY IN RELATION TO PERFORMANCE OF SILKWORM WITH DIFFERENT METHODS AND REGIMES OF FEEDING"** submitted by **MR. B. SANNAPPA** in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY in SERICULTURE** is a record of research work carried out by him during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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BANGALORE
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INTRODUCTION

I. INTRODUCTION

Silk the "Queen of Textiles", unchallenged so far by other fibres, is a nature's gift for man kind. Silk with its fineness, evenness, durability and luster had fascinated the women folk all over the world.

India is the second largest silk producer in the world, next only to China. Of the four commercially exploited silks, mulberry silk accounts 95 per cent of the world silk production. In India, mulberry is cultivated both under rainfed (1,22,496 ha) and irrigated conditions (1,59,748 ha) with a production of 14,048 MT of raw silk. In Karnataka, mulberry is cultivated over 1,66,000 ha which enables to produce 9,236 MT of raw silk (Anon., 1999). Rainfed mulberry cultivation is common in Chamarajanagar, Kollegal and Gundlupet areas of Karnataka.

Besides low productivity, Indian silk industry has failed to produce silk confirming to the International standards to compete in International market. Further, the increasing cost of labour and resources coupled with frequent crop losses may make silk cocoon production less profitable. Hence, it is thought essential to bring about some technological inputs in order to reduce the cost of production without affecting the output thereby making sericulture a stable, viable and more profitable enterprise.

Mulberry (*Morus* spp.) is the sole food plant of silkworm, *Bombyx mori* L. Being monophagous, the silkworm requires specific quality of leaves during different phases of its growth and thus it reflects the importance of mulberry cultivation practices.

The contributing factors for successful cocoon crop production are mulberry leaf (38.2%), climate (37.0%), rearing technique (9.3%), silkworm breed (4.2%), silkworm seed (3.1%) and other factors (8.2%) (Miyashita, 1986). The mulberry production practices play a vital role in determining the cost of production of cocoons, quality and quantity of raw silk. It is estimated that about 60 per cent of the cost of cocoon production goes to mulberry leaf production. Similarly, 70 per cent of the silk produced by silkworm is directly derived from the protein of mulberry leaf. Mulberry leaf protein forms the source for the silkworm to bio-synthesize the silk comprising two proteins, fibroin and sericin (Rangaswamy *et al.,* 1973).

Mulberry leaf quality plays a predominant role in healthy growth of silkworm and the leaf composition depends on various factors *viz.*, mulberry variety, season, irrigation, manurial application, temperature, length of sunshine hours, nature and type of soil profile, water table, pruning, maturity of leaf, method of leaf harvesting etc. Thus it is realised that the native soil fertility alone cannot be relied upon improvement in mulberry leaf yield and quality unless the nutrients in soil are replenished with external sources through fertilizers. Hence, application of manures and fertilizers is important inputs for increasing the leaf yield and quality.

Among the essential plant nutrients, nitrogen, phosphorus and potassium play a vital role in improving both quality and quantity of mulberry leaf and application of these are inevitable as the chemical fertilizers are the key components for higher crop yields in agriculture.

Nitrogen is one of the key elements in mulberry management and silkworm nutrition. Its importance in sericulture need not be stressed upon in view of the high demand for this element both by mulberry for increased leaf yield and silkworm for silk production. Nitrogen is an integral component of many compounds essential for plant growth including chlorophyll and many enzymes. It is an essential component of the proteins and related amino acids, which are critical not only as building blocks for plant tissue but in the cell nuclei and protoplasm in which hereditary control is vested. It is essential for carbohydrate utilization within the plants and stimulates root growth and development as well as the uptake of other nutrients. Of the macronutrients usually applied in commercial fertilizers, nitrogen seems to have the quickest and most pronounced effect. It encourages the aerial vegetative growth and imparts deep green colour to the leaves. It controls the efficient utilization of phosphorus and potassium.

In Karnataka still 39 per cent of mulberry land is under rainfed condition. Inadequate soil moisture is the chief constraint in dry regions where the rainfall is low, highly erratic and punctuated with long dry spells and therefore manurial and fertilizer schedules have to be developed to suit the system.

Mulberry is a deep rooted, perennial plant cultivated for its foliage and thus is different from many other cultivated crop plants. Hence, nitrogen requirement of mulberry is higher than any other agricultural crops and it varies from 50 to 500 kg ha^{-1} depending on the biomass productivity and systems of mulberry cultivation (Bongale, 1993). Crop responses are known to vary with the source of nitrogen. Since mulberry is grown on variety of soils under different agro-climatic conditions, there is a need to work out the appropriate sources of nitrogenous fertilizer required so as to enhance its yield and nutritive quality and inturn the cocoon production and quality of raw silk.

The silkworm rearing practices employed are known to have considerable influence on the ultimate cocoon yield and quality of raw silk. Among them the mulberry leaf quality, method and frequency of feeding and quantity of feed given are also important ones.

The survey on cocoon production and crop loss in Karnataka (Siddappaji *et al.*, 1983 ; 1987) indicated that the method of applying mulberry leaves along with shoots/chopped shoots as practised in Kolar and Bangalore North regions was more productive and economically viable compared to cocoon yield with only whole leaf method adopted elsewhere. Muraleedhara (1990) opined that applying mulberry shoots/shootlets with or without tender flush to silkworms throughout starting from brushing resulted in release of resources which could be utilised otherwise in development of sericulture industry.

Timely provision of nutritionally rich mulberry leaves in optimum quantity to meet the nutritional requirements of silkworms needs to be considered as the most important component as it largely influences cocoon productivity. A feeding frequency of five times a day was found to be the best for getting increased cocoon yield in Karnataka (Narayanan and Chawla, 1965).

In silkworm, a definite pattern of feeding potential exists for various growth phases in every instar. A normal bell shaped curve pattern of feeding is evident in that the feeding potential of the silkworm is low immediately after moulting, then on it increases gradually reaches a peak in the middle of the instar, then gradually drops down and it again becomes less before the worms settle for moult. If feeding schedules are designed taking into consideration the extent of feeding potential in different growth phases of silkworm, it is possible that in addition to meet the optimum nutritional requirements of the silkworms both quantitatively and qualitatively, it may also be possible to prevent the wastage of leaf and brush more disease free layings, reduce the labour input, increase the cocoon yield through the improvement of yield attributing parameters and ultimately realise more net profit from silkworm rearing.

Since sericulture involves both crop and animal husbandry, the crop management on scientific lines should be an approach to provide opportunities to silkworm to express the inherent capacities to produce what it can ! In this context, it was thought necessary to study and understand the effect of different levels of nitrogen on mulberry and feeding of such mulberry through different methods and frequencies to silkworm on silk cocoon production and related economics. Hence, the present investigations have been undertaken with the following objectives.

1. To evaluate the different sources of nitrogen fertilizers for mulberry leaf yield and quality and performance of silkworm.

2. To study the effect of different levels of nitrogen supplied through calcium ammonium nitrate on mulberry leaf yield and quality and performance of silkworm with different methods and frequencies of feeding.

3. To study the correlation between nutritional status of mulberry leaves and economic parameters of silkworm.

4. To workout the benefit-cost ratio of silk cocoon production with different nitrogen levels, methods and frequencies of feeding.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The literature pertaining to studies on the "Effect of nitrogen levels on yield and quality of rainfed mulberry in relation to performance of silkworm with different methods and regimes of feeding" are presented in the following pages.

2.1 EFFECT OF SOURCES OF NITROGEN ON MULBERRY AND SILKWORM

Crop responses are well known to vary with the sources of nitrogen.

Murthy (1953) obtained highest leaf yield of mulberry with ammonium nitrate, followed by calcium ammonium nitrate (CAN) when compared to ammonium sulphate. Further, silkworms fed with leaves raised by the application of ammonium nitrate resulted in higher silk production.

As per Shyamala (1953), the ammonium salts either fed directly or through transpired mulberry leaves resulted in very slight increase in growth of silkworm and silk yield when compared to ammonium nitrate. Application of N in the form of urea or CAN may influence the foliage yield of mulberry. Further, application of CAN is helpful in improving the leaf quality as evidenced by good growth of silkworm and increased silk production.

Higher yields of mulberry can be obtained under conditions of accelerated nitrifying activity of soils especially when N is applied through ammonium sulphate or chloride (Takagishi, 1967).

Kasiviswanathan and Iyengar (1968) obtained non-significant difference in the total leaf yield of mulberry among different forms of N under rainfed condition. However, CAN and urea resulted in 34 and 28 per cent increase in yield over ammonium sulphate. Further, it was opined that ammonium sulphate and ammonium sulphate nitrate are also equally good and can be used as alternative fertilizers.

The relative efficacy of different sources of N fertilizer applied to the mulberry crop in the form of spray at a concentration of 0.5 per cent was in the order of urea>CAN>ammonium nitrate>ammonium sulphate (Manchashetty, 1979).

Mulberry plots treated with CAN yielded significantly higher quantity of leaves than urea treated plots and both were better than control (Anon., 1986a).

Rajanna *et al.* (1988) obtained the highest leaf yield with urea super granules followed by CAN and urea along with P and K under rainfed situation. However, the lowest leaf yield was recorded with urea when no P and K were added. Further, CAN was superior to other nitrogenous fertilizers in getting better cocoon yield and commercial characters of cocoons viz., cocoon, pupal and shell weights, shell ratio and single cocoon filament length.

Application of complex fertilizer (15 all of NPK) as basal dose followed by ammonium chloride - CAN or urea or ammonium sulphate as top dressing improved the leaf yield (15 to 18%) and nutritional quality of mulberry, silkworm growth and development, cocoon and post cocoon parameters over the application of ammonium chloride as basal dose followed by ammonium chloride for top dressing (Sreenivasa Shetty, 1988).

Shankar (1990) obtained higher leaf yield of mulberry by using urea and CAN. Significantly higher cocoon and shell weights were obtained when silkworms were fed with mulberry leaves obtained with CAN and urea-gypsum. Similar observations were made by Teotia *et al.* (1992) as per whom the application of urea and CAN in acidic mulberry soils (4.38 pH) significantly increased the crude protein, leaf yield and growth parameters namely, height of the plant and number of leaves per metre height.

Larvae of NB_7 silkworm breed fed with M_5 mulberry leaves fertilized with different sources of nitrogenous fertilizers had a profound influence on cocoon characters. N through CAN registered highest cocoon weight (1.596g), pupal weight (1.292g), shell weight (0.409g), shell ratio (16.66%) and single cocoon filament length (850.0m) over other sources under irrigated condition (Subbarayappa *et al.,* 1992).

Manjula (1993) observed that feeding of mulberry leaves obtained from plants after CAN application significantly increased full grown larval weight, cocoon weight, shell weight, shell ratio and single cocoon filament length when compared to other sources, since CAN does supply N in both ammonical and nitrate forms which is beneficial for differential uptake of N by mulberry.

Shankar and Shivashankar (1993 and 1994) opined that CAN and urea granules are the best sources of N to mulberry in harvesting best quality leaf suitable for late-age silkworm and to improve the industrial properties of silk.

Mulberry leaves raised through urea upper granules gave the higher leaf yield of 36,875 kg/ha/yr over CAN (33,105 kg), urea (31,720 kg), urea with calcium (30,976 kg) and neem cake blended urea (29,921 kg) along with recommended P and K, while plots that received urea alone gave the lower yield (26,875 kg) under irrigated condition (Rajanna and and Dandin, 1994).

Manjula and Shankar (1995) recorded the highest leaf yield and best growth performance of mulberry when supplied with CAN, ammonium nitrate and 15 - all (a complex fertilizer) when compared to other nitrogenous sources.

As per Subbarayappa *et al.* (1995), application of CAN with P and K significantly increased the leaf area, leaf yield, P, K and total mineral content of mulberry leaves over other sources and control.

Subbaswamy *et al.* (1999b) observed that application of ammonium sulphate to mulberry resulted in significantly higher leaf yield (40.15 MT/ha/yr), N (4.18%), protein nitrogen (3.31%) and iron (0.36%) as compared to that of plants which received urea or CAN as sources of N. Further, rearing results indicated that cocoon yield/100 dfls increased substantially when silkworms were fed with leaf from ammonium sulphate treated plot (58.2 kg) as compared to urea (46.0 kg) and thus the effectiveness of these fertilizers in mulberry varied in the sequence of ammonium sulphate>urea>CAN under irrigated condition.

Among the nitrogenous sources, the use of CAN was found to significantly increase the fecundity (512.51 eggs/laying) and hatchability (93.52%) of NB_4D_2 breed of silkworm (Shankar *et al.*, 1999).

The review suggests that application of N in the form of urea or CAN may influence the foliage yield of mulberry. Application of CAN is helpful in improving the quality of leaf as evidenced through enhanced growth of silkworm and increased silk productivity.

2.2 EFFECT OF NITROGEN LEVELS ON THE PERFORMANCE OF MULBERRY AND SILKWORM

Mulberry is known to respond differentially with levels of N.

According to Ushioda (1954), N has the greatest influence on the quality of mulberry leaves. Higher N increased protein and moisture contents of leaves and decreased the percentage of sugars, phosphoric acid, potash and calcium. However, increase in amounts of phosphorus, potassium and calcium in mulberry decreased the N content of leaves at constant N level. Further, the mulberry leaves grown with higher nitrogenous fertilizer were generally not suitable for rearing young-age larvae, but suitable for grown up larvae.

According to Yokoyama (1962a), the higher dose of N was effective in increasing the foliage yield but from the point of silkworm rearing, leaves obtained with higher N were inferior in quality.

Kasiviswanathan and Iyengar (1965) reported that application of 75 to 100 kg N/ha/yr in a single dose was beneficial for growth of mulberry saplings and application of N upto 100 kg/ha/yr increased leaf yield significantly. Further, the response to N increased with moisture availability.

Pain (1965) reported that application of N increased the crude protein content of leaves from 16.6 to 21.5 per cent, while moisture, starch, crude fibre and mineral contents in leaves remained unaffected by N levels.

Narayanan *et al.* (1966) observed that feeding of silkworms with leaves of mulberry grown under N fertilization significantly increased the full grown larval weight, cocoon weight, shell weight, single cocoon filament length and denier. Further, even the application of 200 kg N/ha/yr was not harmful to any of the cocoon characters.

Application of N @ 50 kg/ha/yr to mulberry under rainfed condition significantly increased the leaf yield over no N and the increase worked out to be 24 per cent, but this increase in yield was upto 100 kg N/ha/yr. Further, the differences in yield among 100, 150 and 200 kg N/ha/yr application were found non-significant (Anon., 1967 and Kasiviswanathan and Iyengar, 1969).

Foliar application of urea @ 1.5 per cent along with 50 kg N/ha/yr applied to soil markedly increased the leaf yield (13,900 kg/ha/yr) over control, where there was no application of fertilizer (9,506 kg) and contributes for 46.2 per cent increase over control (Anon., 1969a).

Kasiviswanathan and Iyengar (1970) found that split application of 200 kg N/ha/yr significantly increased the mulberry leaf yield (27,354 kg/ha/yr) over 100 kg (23,887 kg). Further, it was found that mulberry can utilize all the available nutrients for its full yield expansion under no moisture shortage.

Split application of N (180 kg in 3 doses) was more effective than single application (180 kg) of basic dose for increasing the mulberry leaf yield. The yield increased in proportion to the increase in the dose of N fertilizer. The increase was 18.8 per cent when 180 kg N was applied in 3 splits over 12 per cent increase by single application of 90 kg N (Abbasov *et al.*, 1970).

Kasiviswanathan *et al.* (1970) reported that the two levels of N @ 100 and 200 kg/ha/yr were not significant for the larval weight, shell weight and denier. However, cocoon weight and single cocoon filament length were found significant. Thus the two levels of N do not appear to have influenced the quality of leaves in an appreciable manner.

Continuous application of N fertilizer specially at 100 to 200 kg/ha/yr for four years gave higher leaf yield in fifth year due to residual effect, during which year N was not applied. The increase for residual 50,100,150 and 200 kg N/ha/yr worked out to be 9.8, 38, 39 and 76 per cent over no N application. The differences in leaf yield among graded doses of N were greater under rainfed condition than under irrigation (Kasiviswanathan and Iyengar, 1971). Further, it was inferred that it is necessary to apply N for sustained productivity even under irrigated condition to reap the full benefit of irrigation. Application of N favoured slightly higher cocoon yield, silk percentage and filament length, while mature larval weight, cocoon weight, shell weight and denier were not influenced by N fertilization.

Application of N @ 900 kg/ha/yr significantly improved the economic characters of silkworm apart from cocoon yield and absolute silk content and there was no harmful effect on silkworm growth (Krishnaswami *et al.*, 1971).

Higher dose of N fertilization beyond 300 kg N/ha/yr recorded fairly consistent increase in mulberry leaf yield of about 5 to 6 per cent for each additional application of 100 kg N/ha/yr. The added N had some effect on higher protein synthesis in the leaves. However, there was no significant effect of levels of N fertilization on cocoon quality (Sengupta *et al.,* 1972).

Sengupta *et al.* (1973) found that levels of N fertilization indicated a definite effect on the improvement of cocoon characters but between the range of 0 and 300 kg of added N/ha/yr only, beyond which the effect of N has been almost exclusively on the higher productivity of leaf and resultant higher cocoon productivity rather than significant improvement on cocoon quality.

The study on the application of N as foliar and soil application revealed that soil application @ 50 kg N/ha/yr + foliar application @ 50 kg N/ha/yr gave the highest leaf moisture, crude protein and total carbohydrates over the other treatments under rainfed condition (Anon., 1973a).

Progressive increase was obtained in mulberry leaf yield for every additional dose of N upto 100 kg/ha/yr. The increase in yield over control worked out to be 8.8, 22.5, 34.5 and 53.0 per cent for 25, 50, 75 and 100 kg N/ha/yr application, respectively (Anon., 1973b).

Application of 100 kg N/ha/yr significantly increased the leaf yield (12.8%) over 50 kg. Further, 31.2 kg of additional leaf yield was obtained for every kg of N supplied (Anon., 1973c).

Kasiviswanathan and Venkataramu (1973) noticed an increase in yield upto 900 kg N/ha/yr, but increase in foliage yield beyond 600 kg N/ha/yr was not significant. Further, higher N also improved the total sugar content of the leaf, larval weight, shell weight and absolute silk content. Similar trend was also observed at CSR&TI, Mysore (Anon., 1976a).

Ray *et al.* (1973) found that application of N was found to increase the crude protein content in mulberry leaves with marginal decrease in the total mineral content. On the contrary, Katak *et al.* (1979) reported that N application significantly increased the fresh weight of leaves but did not influence the protein content.

Basavanna *et al.* (1974) observed that application of 900 kg N/ha/yr increased the crude protein content of 3.89 per cent. K_2 mulberry variety spaced at 45x10 cm with a N level of 300 kg N/ha/yr had considerably increased crude protein content.

There was a progressive and significant increase in total leaf yield of mulberry upto 600 kg N/ha/yr (33.476 kg/ha/yr) over 900 kg (31,971 kg) and the difference existed between them was non-significant (Anon., 1975a).

Soil application of 100 kg N/ha/yr and half soil + half foliar application of 100 kg N/ha/yr gave significantly higher leaf yield of mulberry over others and the increase worked out to be 129 and 90 per cent over control, respectively (Anon., 1975b and Verma *et al.*, 1975).

Basavanna *et al.* (1976) observed that soil application of N at 100 kg/ha/yr improved the starch and crude protein content of mulberry leaves. Further, foliar application of N at 100 kg/ha/yr decreased all these qualities including crude protein and starch content of leaves.

Choudhury *et al.* (1976), Kasiviswanathan *et al.* (1977) and Jolly (1981) reported that there was a progressive and significant increase in leaf yield upto 600 kg N/ha/yr under irrigated conditions. However, application of 300 kg N/ha/yr can preferred in view of economics of leaf production.

Roy (1978) opined that combination of soil and foliar application of urea produced maximum foliage yield in mulberry as compared to exclusive soil or foliar application alone.

Kasiviswanathan *et al.* (1979) reported that the mulberry variety M_5 with a spacing of 45x23cm and application of N @ 900 kg/ha/yr recorded significantly higher leaf yield (43,944 kg/ha/yr) over other treatment combinations tried under irrigated condition. Application of 600 kg N/ha/yr increased the leaf yield significantly by 15.6 and 19.9 per cent during first and second year of mulberry cultivation, respectively, over 300 kg N/ha/yr (Kasiviswanathan *et al.*, 1980).

A highly significant correlation was found between the N content (4 - 4.5%) in leaf and the silkworm body weight, cocoon weight and shell weight (Sudo *et al.*, 1981).

Varied levels of N had a significant influence on the leaf yield of mulberry. Application of N @ 400 kg/ha/yr recorded yield of 26,033.15 kg/ha/yr over control (Anon., 1984a).

Foliar application of N showed an increase in the total leaf yield of mulberry over control. Supply of N 50 per cent through foliar and

50 per cent through soil was found to be more effective than exclusively through soil (Anon., 1984b).

Samsijah (1985) while assessing the nutritive value of mulberry leaves on silkworm rearing observed that application of 100 kg N/ha/yr had good influence in increasing the silkworm survival and shell weight when compared to higher doses of N.

Ahmad (1986) reported that the application of N @ 100, 200 and 300 kg N/ha/yr significantly increased the leaf yield to the extent of 78.8, 120 and 175 per cent, while it was 55, 100 and 120 per cent during first and second year of mulberry cultivation, respectively over check where no N was used.

Foliar application of urea to an extent of 100 per cent (100 kg N/ha/yr) significantly increased the leaf yield (46.60%) over 100 per cent soil application (100 kg N/ha/yr). However, 50 per cent foliar and 50 per cent soil application was found superior (38.70%) to 100 per cent soil application at fortnightly interval with 0.5, 1.0 and 1.5 per cent concentration in field condition (Fotedar and Chakraborty, 1986).

Venugopala Pillai *et al.* (1987) reported that K_2 when cultivated with 45x45cm spacing and 900 kg N/ha/yr improved the feeding quality of the leaves and also to great extent increased the growth rate, survival rate, cocoon yield, silk output and egg production over other treatments.

Studies conducted on the effect of different levels of N (0,100, 200, 300 and 400 kg N/ha/yr) on leaf yield of mulberry indicated that the yield increased upto maximum level of 400 kg N/ha/yr and the increase was 54 per cent over control (Fotedar *et al.*, 1988).

Rajanna *et al.* (1988) observed that plant height, shoot length, fresh and dry weight of leaves and leaf yield recorded significant variation among different N levels, while leaf moisture percentage not shown any significant variation.

Qaiyyum *et al.* (1989) reported that plant height, number of branches/plant, leaf number/branch, leaf area, stem height and leaf yield/plant could be substantially increased by spraying urea on the leaf which ensures 22.94 to 27.63 per cent increased leaf yield in mulberry and the doses of 0.5 and 1.0 per cent could be most effective and may be recommended for commercial use.

According to Chaluvachari *et al.* (1992), there was general improvement in the growth and yield of mulberry upto 100 mg N/kg soil. The soluble proteins, chlorophyll and moisture contents (20.0%, 2.26 mg/g and 73.6%) were higher with 200 mg N/kg soil compared to control without N input (14.6, 1.54 and 70.4), while sugar content and root biomass were reduced with consequent increase in N levels.

Das *et al.* (1993) reported that application of 150 kg N/ha/yr increase the leaf yield of rainfed mulberry garden over 50 and 100 kg N/ha/yr by 26.6 and 13.0 per cent, respectively. Except for the leaf-cocoon ratio and absolute silk content, non-significant differences existed for other economic characters of silkworm (NB_7 x NB_{18}) due to different N levels.

Leaf yield and productivity of mulberry varied with the levels of N and application of 300 and 450 kg/ha/yr recorded an yield increment of 5,666 and 10,942 kg/ha/yr as compared to 150 kg/ha/yr and hence every additional kg of N applied over 150 kg/ha/yr had resulted in 36 kg leaf yield (Rajanna and Dandin, 1994).

According to Potdar (1994), Sudharshana Reddy (1994), Potdar *et al.* (1997a and 1997b), higher dose of N (400 kg/ha/yr) recorded superiority in respect of yield and quality of mulberry leaves, subsequently on growth and development of silkworm and cocoon parameters over 0 and 200 kg N/ha/yr, but not with 250, 300 and 350 kg N/ha/yr. Application of N did not increase the incidence of grasserie.

As per Sridhara *et al.* (1995), 100 kg N/ha/yr applied as 100 per cent foliar spray recorded leaf yield of 26.2 t/ha/yr which was significantly higher to 300 kg N/ha/yr (22.7 t) applied as 100 per cent soil application and almost equal to 300 kg N/ha/yr (26.1 t) applied as 50 per cent foliar spray + 50 per cent soil application.

Patra (1996) observed superiority in respect of larval and cocoon characters with the application of 150 kg N/ha/yr over control (100 kg N/ha/yr). Patra and Shankar (1998) reported that the advantage of higher N supply to rainfed mulberry (150 kg/ha/yr) over control (100 kg/ha/yr) could not be realised in terms of fresh leaf yield/plant which may be due to the fact that the moisture content of soil was not sufficient to utilize the available N as evidenced by significant increase in their dry weight (81.01g) due to application of higher level of N when compared to control (74.79g).

Bose and Majumder (1999) studied the biomass production of mulberry with different levels of N fertilization. Application of N @ 400 kg/ha/yr significantly increased the leaf yield (48.28 t/ha/yr) over 300 kg (41.48 t) and 200 kg (33.15 t).

It is thus seen that the response of mulberry to levels of N is dependent on soil type and moisture status. Irrigated mulberry is observed to respond upto 900 kg N/ha/yr in a number of cases. Besides increased leaf production, N also improves the quality of leaf for silkworm which inturn increases cocoon yield and silk content.

2.3 EFFECT OF NPK LEVELS ON THE PERFORMANCE OF MULBERRY AND SILKWORM

Application schedule of chemical fertilizers differs among regions with respect to the climatic conditions and cultivation practices. In China, dosages of fertilizer application differ according to the type of cocoons being produced. NPK is applied @ 350:150:200 kg/ha/yr for seed cocoon production as against 300:100:150 kg/ha/yr for commercial cocoon production. Application of N up to 500 kg/ha/yr is also commonly followed in commercial farms. NPK fertilizers are applied in four split dosages. In Japan, 250-360 kg N, 150-170 kg P and 150-200 kg K/ha/yr are applied. Chawki mulberry plots generally receive about 20 per cent less N and more of P and K compared to those meant for late-age silkworms. In Bangladesh, NPK @ 200:60:45 kg/ha/yr in four split doses are applied. In Vietnam, NPK is applied in the ratio of 3:1:1 in addition to 30 MT of FYM (Bongale, 1994).

In India, fertilizers are applied to mulberry in different doses in different parts of the country. In temperate region covering Himalayan belt, the fertilizers are applied @ 100:50:50 kg NPK/ha/yr in two split doses. In sub-tropical region covering the sub-Himalayan region, fertilizers are applied @ 336:180:112 kg NPK/ha/yr in four split doses. In tropical region covering the rest of the country, NPK is applied @ 50:25:25 kg in two split doses for rainfed condition during the first year of establishment. First dose of 25:25:25 kg NPK is given for two months old plantation and second dose is given @ 25 kg N before the cessation of monsoon or at the time of post monsoon rains during October to November. Second year onwards, NPK is applied @ 100:50:50 kg/ha/yr in two split doses. First dose of 50:50:50 kg NPK is applied following the first leaf harvest i.e., during late August and the second dose of 50 kg N is applied 2 to 3 weeks after the second leaf harvest (Bongale, 1994). In tropical region under irrigated condition, first dose of 50:50:50 kg NPK/ha/yr is applied during the first year of establishment and first harvest is taken after six months of fertilizer application. Second dose of 50 kg N is applied 3 to 4 weeks after the first harvest. Second year onwards, NPK applied @ 300:120:120 kg/ha/yr in the case of row system where five harvests are made. Two split application of 60:60:60 kg NPK is given for first and third harvest and 60 kg N is given for second, fourth and fifth harvests. In the case of pit system with leaf picking for six times NPK is applied @ 280:120:120 kg/ha/yr. NPK @ 60:60:60 kg is applied for first and fourth harvests and 40 kg N is applied for the remaining (2^{nd}, 3^{rd}, 5^{th} and 6^{th}) harvests (Jolly, 1987; Bongale, 1994).

Novatskaya (1959) obtained increased surface area and weight of mulberry leaves with foliar application of N, P and NPK. Foliar application of N at 0.75 per cent concentration gave 11 to 16 per cent more leaf yield compared to soil application of 50 kg N/ha/yr as ammonium sulphate and urea.

Ide and Okada (1963) opined that too high doses of N fertilizer applied to mulberry without P and K deteriorate the feed value of the leaves.

Pain (1965) revealed that N fertilization was found to enhance leaf and shoot yield of mulberry more than that with the application of P and K. However, highest leaf yield was obtained with NPK combinations and the treatments where N was lacking comparatively less yields were obtained though they were higher than that of control.

Kasiviswanathan and Iyengar (1966) found that application of 200:100:50 kg NPK/ha/yr gave 40 per cent increase in leaf yield of mulberry compared to control. Further, application of N and K increased the moisture content of leaves but only N application decreased the ash content by 1.5 per cent.

Kasiviswanathan and Iyengar (1970) reported that effect of nutrients on mulberry leaf yield in general to be influenced more by N than other nutrients. Highest leaf yield was obtained in treatment combination of N (336 kg), P (180 kg), K (112 kg) and FYM (22 MT) per hectare per year and increase in leaf yield was as much as 81.0 per cent.

Sidhu *et al.* (1969) found that leaves of mulberry plants grown under NPK fertilizers @ 200:100:50 kg/ha/yr improved the larval growth, cocoon yield and cocoon characters.

Ray *et al.* (1973) observed that application of NPK @ 336:180:112 and FYM 22,000 kg/ha/yr not only increased the leaf yield (80.9%) but also increased the crude protein, starch, minerals and moisture contents.

Soil and foliar application of N (50:50) @ 50 kg/ha/yr each recorded higher moisture (68.39%), crude protein (22.65%), starch (6.15%) and total carbohydrates (12.16%), while total minerals, reducing sugars and total sugars were higher with soil application of NPK @ 100:50:50 kg/ha/yr over other combinations and control (Anon., 1975c).

Work carried out at CSR&TI, Mysore indicates that application of higher dose of N in combination with P and K increased the crude protein content from 15 to 23 per cent, while other constituents in the mulberry leaf did not differ in any of the treatments tried (Anon., 1976b)

As per Ullal and Narasimhanna (1981), the recommended FYM and NPK are 10 and 20 tonnes and 100:50:50 and 280:120:120 kg/ha/yr for rainfed and irrigated mulberry, respectively.

According to Shivashankar and Krishnamurthy (1978), application of P and K is essential in addition to N to enhance the mulberry leaf yield. Supply of K along with N not only increased the leaf yield but caused a characteristic smell in the leaves for improving the feeding value (Madhava Rao, 1982).

Application of NPK to soil as well as foliar spray of N at 0.5 per cent increased the mulberry leaf yield (21.24%), crude protein and total mineral contents (Manchashetty, 1979).

Application of 100:25:62.5 kg NPK/ha/yr improved the mulberry leaf yield in peat soils of Malaysia (Chew *et al.*, 1980).

Chauhan *et al.* (1985) concluded that balanced levels of N, P and K significantly improved the leaf yield of mulberry when applied @ 100:100:150 g/tree.

Takagishi and Kawanchi (1985) reported that the increase in N content along with P was associated with a pronounced increase in arginine, aspargine, aspartic acid and nitrate nitrogen.

Takagishi *et al.* (1985) observed that the supply of P and K along with N resulted in the increased body weight of the silkworm and cocoon production significantly.

Jolly (1986b) suggested that application of 20 t/ha/yr FYM as a basal dose and 255:255:255 kg NPK/ha/yr was better under irrigated condition for harvesting superior quality of leaf required for chawki worms.

Rangaswamy *et al.* (1999) observed that the application of NPK @ 400:120:200 kg/ha/yr in five splits gave significantly higher chlorophyll (2.62 mg/g), moisture (73.04%), N (3.16%), P (0.61%), K (2.42%) and Ca (1.68%) over other combinations. The Mg and S contents of leaves did not differ much. Further, feeding of worms on such mulberry leaves recorded higher cocoon (1.649g), pupal (1.370g) and shell (0.278g) weights and filament length (880.0m) (Rangaswamy, 1997).

Raje Gowda *et al.* (1999c) reported that application of N and K @ 400:180 kg/ha/yr gave significantly higher number of shoots/plant (15.25), shoot height (83.66cm), number of leaves/plant (206.81), leaf yield/plant (222.6g) and leaf yield/ha/yr (30,574.25.25 kg) as compared to the present recommended dosage of 300:120 kg/ha/yr. Similarly, moisture content (72.60%) as well as chlorophyll content (2.31 mg/g) were also significantly higher with the same treatment combination.

Bhaskar *et al.* (1999) revealed that the varied levels of NPK (200-280:80-140:80-140 kg/ha/yr) on M_5 mulberry had influenced the growth parameters. Higher levels of NPK (280:140:120 kg/ha/yr) recorded maximum shoot height (250 cm) and it was minimum in control (183 cm). Further, the shoot height was not related to the number of shoots (8.86/plant).

The study on varied levels of NPK fertilizers to mulberry indicated that, application of NPK @ 360:120:180 kg/ha/yr recorded significantly higher N (3.442%), P (0.602%), K (2.067%) Ca (3.006%), Mg (0.742%) and S (0.287%) as compared to other treatment combinations and control (2.233, 0.416, 1.775, 1.882, 0.483 and 0.133%, respectively) (Mareppa *et al.*, 1999a).

Subbaswamy *et al.* (1999a) observed that application of N and P at 2:1 ratio recorded significantly higher quantity of protein-nitrogen (3.0%) and P (0.57%) over control indicating a clear improvement in leaf quality. Further, cocoon yield/100 dfls as well as single cocoon weight increased significantly when worms were reared on such leaves.

Mareppa *et al.* (1999b) noticed that application of N(CAN)PK @ 360:120:180 kg/ha/yr to mulberry and feeding of such leaves to silkworm (PM x NB_4D_2) yielded higher cocoon weight (19.34 g/10), shell weight (2.983 g/10) and shell ratio (15.42%). Further, application of fertilizers @ 360:120:120 and 360:120:60 kg/ha/yr performed as next best combination with regard to cocoon parameters.

Application of N+K_2SO_4 in combination @ 400:180 kg/ha/yr recorded significantly higher mature larval weight (16.64 and 37.00

g/10), cocoon weight (1.113 and 2.011 g), shell weight (0.134 and 0.372 g) with respect to PM and NB_4D_2 breeds, respectively when compared to the normal practice of N and KCl application @ 300:120 kg/ha/yr. Similar trend was also observed with regard to the rate of moth emergence fecundity and hatchability in both PM and NB_4D_2 (Raje Gowda *et al.,* 1999a).

Mareppa (1999) observed positive correlation between ERR with chlorophyll 'a' 'b', N, P and Mg ; mature larval weight with total chlorophyll, Ca, and S ; cocoon parameters with crude protein, total chlorophyll, N, K, Ca and S, but negative correlation with moisture content of leaves when mulberry was supplied with varied levels of N and K.

The above review indicates that application of N, P and K in balanced proportion will enhance foliage yield and growth and development of silkworm with better cocoon and post-cocoon parameters.

2.4 INFLUENCE OF METHODS OF FEEDING ON THE PERFORMANCE OF SILKWORM

The method/form of offering mulberry to silkworms along with the frequency and the quantity of leaf provided are known to influence the performance of silkworm, *Bombyx mori* L.

In practice, the commercial cocoon production is carried out by adopting shelf rearing method on circular bamboo trays. Several modifications have been tried with the main object of providing a continuous supply of fresh mulberry leaves and to reduce the labour involved in cleaning, spacing and feeding silkworms, thus minimizing the cost of production.

The methods described (Anon., 1956) were (i) rearing silkworms with chopped mulberry buds-where apical or terminal buds chopped into two or three pieces are applied to silkworms five times a day during first instar and four times during second instar ; (ii) rearing worms with chopped mulberry leaves and branches-chopped mulberry leaves are applied in first instar, chopped buds in the second instar and then onwards whole shoots till ripening and (iii) shoot feeding where mulberry leaves intact with branches are applied to silkworms. The latter method originated in Italy and France and gradually spread to Japan. The main object of this method is to reduce the labour cost involved during first instar. The three broad systems of rearing recognized are (a) "Systema gratici" - silkworms are reared in wooden trays with chopped mulberry leaves in all the instars ; (b) "Systema fruilana" - worms are reared in wooden trays upto fourth instar and fifth instar worms are provided with mulberry shoots and (c) "Systema cavallone" - the fifth instar worms are provided with branches. In this system the mulberry branches are placed in a receptacle filled with water and used for rearing first and second instar worms.

Yokoyama (1962b) reported different methods of harvesting mulberry leaves for rearing of chawki worms. They are (i) leaf plucking - adopted for rearing silkworms with chopped leaves or entire leaves ; (ii) shoot plucking - silkworms are fed with chopped or entire mulberry shoots and (iii) top cutting of shoots - seldom adopted for providing the silkworms with leaves on branches. The chopped leaves are rarely used for rearing first instar larvae in spring and upto third instar in summer and autumn rearings, while chopped shoots are applied to silkworms upto second instar in spring and autumn rearings.

The mulberry leaves are said to be applied to silkworms differently under different systems of rearing as follows (Anon., 1972).

(i) Shoot rearing: Silkworms after third moult are reared on a raised bed on the floor of rearing room and applied with mulberry shoots.

(ii) Shelf rearing: The conventional method of rearing silkworms in bamboo trays arranged in tiers on a shelf and applied with plucked leaves.

(iii) Flat rearing: The rearing seat is prepared about 80cm above ground level, occasionally in two or three tiers and the silkworms are applied with plucked mulberry leaves.

Kasiviswanathan *et al.* (1970) found that silkworm ($PMxC_{108}$) cocoon crop raised by selective leaf feeding had higher weight of ripened larva (2.232g), cocoon weight (1.17g), shell weight (0.17g), filament length (507m) compared to that of silkworms fed with shoots (1.990g, 1.09g, 0.16g and 440m, respectively).

Krishnaswami *et al.* (1970) observed that the weight of ripened larva of MBD_5 silkworm reared on twigs with leaves of Local mulberry was 1.96g and it was higher compared to that of plucked leaves (1.90g). The weight of ripened larva of Nistari was 2.02g when supplied with tender leaves (top 10 leaves excluding the growing tip of two or three leaves) throughout the larval period and was higher compared to the rest of the treatments, using leaves of varying maturity at different instars of silkworm. Higher ERR (59.21%), cocoon weight (0.95g), shell weight (0.133g) and shell ratio (14.1%) were observed when silkworms were reared on mulberry twigs with leaves compared to the respective values of 53.41 per cent, 0.93g, 0.127g and 13.6 per cent, respectively when reared on the plucked mulberry leaves.

Krishnaswami *et al.* (1977) reported that the larval duration of KA was 27.10 days with entire leaves and 26.23 days with chopped leaves and the weight of ripened worm was 2.78 and 2.74g, respectively.

As per Ullal and Narasimhanna (1981), providing chopped mulberry leaves not only results in wastage of leaves but also chopped leaves dry sooner than the entire leaves. Both shoot harvest and branch pruning help to reduce withering of mulberry leaves after harvest as the leaves remain attached to stem intact. Besides, in these methods tried, the leaf was better preserved in addition to savings on cost of leaf harvest.

The bivoltine hybrid, NB_7 x NB_{18} had the highest ripened worm weight (3.86g), cocoon weight (1.688g) and shell weight (0.331g) in case of worms reared on chopped leaves throughout compared to that of the worms fed with the whole leaves upto third instar and then with shootlets till ripening (2.78, 1.435 and 0.288g, respectively) (Anon., 1983a).

Application of chopped mulberry leaves to silkworm (Nistari) upto second instar alternated with shoot feeding till ripening resulted in significantly higher larval weight at ripening (2.13g), ERR (96.96%), cocoon weight (0.926g), shell weight (0.126g) and shell ratio (13.55%) compared to that of silkworms fed with whole leaves from third instar onwards (1.96g, 95.51%, 0.852g, 0.111g and 13.03%, respectively) (Anon., 1986b).

Siddappaji (1986) revealed that shootlet feeding for chawki worms increased the cocoon yield and ERR and reduced the required man hours (12.20 %) and renditta.

The performance of Nistari and its hybrid (Nistari x G) with a schedule of four feeds a day upto second instar followed by shoot feeding in later instars was found to be superior with regard to the weight of ripened larvae, ERR, weights of cocoon and silk shell, shell percentage, filament length, denier and cocoon yield/100 dfls (Anon., 1987a).

Chikkavenkateshappa (1987) investigated on methods of application of feed viz., the entire leaves, chopped leaves, entire shoots without tender flush and only the tender flush of mulberry (M_5), from third instar onwards to silkworm hybrid, $PMxNB_4D_2$. Best performance was noticed in respect of larval weight, ERR, cocoon weight, pupal weight, shell weight, shell ratio, reelable silk filament length, denier and renditta when silkworms were reared on the entire shoots without tender flush indicating the alround improvement including silk quality.

Muraleedhara (1990) studied the influence of methods of feeding silkworm namely whole leaves, whole leaves cut into two bits, whole shoots with tender flush and without tender flush, chopped shoots with tender flush and without tender flush. Whole shoots with tender flush registered higher ripened larval weight (3.42g), cocoon weight (1.82g), pupal weight (1.46g), shell weight (0.341g) and shell ratio (18.77%), filament length (899m). Whereas ERR was higher on whole leaves (44.86%) compared to other methods and check during August - September.

Kumar and Benchamin (1990) observed that the survival rate, cocoon yield and absolute silk content of the bivoltine hybrid (NB_{18} x NB_7) were significantly increased by 11.5, 17.0 and 18.0 per cent, respectively when the first to fifth instar larvae were fed on high stem pruned mulberry (35cm above ground level) and fourth and fifth instar larvae on basal pruned mulberry leaves as compared with the larvae fed continuously on the leaves from basal pruned plants.

The mulberry leaves intact with shoots were found to preserve the acceptability, turgidity and palatability of leaves leading to increased feeding efficiency of silkworm. Transfering neonate silkworms, without brushing with feather, by offering mulberry twigs/entire shoots with or without tender flush throughout till ripening with many fold advantages viz., conservation of "on farm and off farm" resources, marked decrease in leaf - cocoon ratio, larval duration, labour input and the corresponding reduction in cost of cocoon production and renditta and increase in body building matter of chawki worms, ERR, cocoon yield, silk ratio, length of the reelable filament and denier indicating an alround improvement (Siddappaji *et al.*,1992).

Shekarappa *et al.* (1994), suggested single feed/day during young-age by providing entire tender leaves and shootlets with 4-5 leaves so as to enhance the larval weight, ERR and cocoon weight and to save about 30-50 per cent of leaves and mandays by 30-73 per cent.

Badiger and Patil (1999) studied on the impact of leaf and shoot feeding of three improved mulberry varieties (S_{41}, S_{54} and M_5) on the performance of NB_{18} silkworm breed. Shoot feeding method was significantly superior to leaf method among all mulberry varieties.

Maheshkumar Vage and Ashoka (1999a) reported that the fifth instar larvae (PM x NB_4D_2) fed with tender shoots of mulberry upto three days followed by matured shoots registered higher values for larval weight (31.56 - 36.13 g/10 larvae), ERR (77.33 - 88.66%), cocoon yield by weight (274 - 314 g/200 larvae), silk productivity (4.89 - 5.28 cg/day) and lower incidence of grasserie (5.00 - 8.66%) in all the seasons over other treatments.

Fifth instar larvae of PM x NB_4D_2 when fed with tender shoots upto three days and subsequently with matured shoots yielded higher values for cocoon weight (17.86, 17.08 and 19.24g), shell weight (3.21, 3.01 and 3.48g), shell percentage (17.96, 17.63 and 18.12), filament length (735.16, 720.23 and 745.23m) and filament weight (0.186, 0.182 and 0.187g) during summer, rainy and winter seasons, respectively (Maheshkumar Vage and Ashoka, 1999b).

The review indicated that, feeding silkworms through whole mulberry shoots performed better over leaf feeding in respect of larval growth and development and cocoon characters.

2.5 INFLUENCE OF FREQUENCY OF FEEDING ON THE PERFORMANCE OF SILKWORM

Feeding frequency perhaps is the most important factor in silkworm rearing as it has direct effect on the growth and development of worms on one side and with the cost of silkworm rearing on the other. Further, silkworm is a voracious feeder during the last two instars and requires to be fed a number of times for better and uniform larval growth and development. The number of feeds given varies from place to place depending upon many factors.

Several factors namely, mulberry leaf quality, time of harvesting, method and duration of storage of mulberry, feeding method, way of chopping, appetite of silkworms, silkworm breeds/hybrids, larval instar and temperature and relative humidity existing in the rearing room are known to decide the feeding frequency in silkworm rearing so as to harvest better cocoon crops (Yonemura and Ramarao, 1925).

It was found at CSR&TI, Mysore that Shungetsu Hosho race of silkworm when fed 3, 4 and 5 feeds/day did not have significant influence on the growth and development (Anon., 1965). Similarly, PM x HS_6 was not influenced in respect of ERR and economic characters of cocoon (Anon., 1972).

Narayanan and Chawla (1965) investigated on the effect of feeding frequency of 3, 4 and 5 feeds/day throughout the larval stage in two breeds of silkworm viz., PM and Shungetsu Hosho. Significant differences seldom existed among the feeding frequencies as judged by the quantitative characters studied. However, cocoon weight in both the breeds, filament length in PM and denier with 5 feeds/day and shell weight in both the breeds, floss percentge and filament length in Shungetsu Hosho and denier in PM with 4 feeds/day were maximum, while only floss percentage was maximum with 3 feeds/day.

Experiments at CSR&TI, Berhampore with two silkworm breeds namely Nistari and MBD_5 in three rearings with five feeding schedules of 2, 3, 4, 5 and 6 feeds/day from third instar indicated in consistent results with 5 or 6 feeds/day (Anon., 1969b). In June - July rearing 6 feeds/day was better than all other treatments except for ERR in both the breeds and shell weight in Nistari. In August-September rearing, 5 and 6 feeds were better for all characters in Nistari, except for maximum larval weight and ERR. But in November-December 5 and 6 feeds/day were superior but mature larval weight in MBD_5 and ERR in both Nistari and MBD_5.

According to Antonio *et al.* (1972), among five combinations of treatments tested, the combination of 2 feeds/day and covering of mulberry leaves with cloth in the rearing bed was statistically superior to the others.

The ERR and other economic characters of silkworm hybrid, PM x HS_6 were correlated with feeding frequency of 2, 3, 4 and 5 feeds/day (Narasimhanna and Sudhakaran, 1973). Feeding frequency of 5 feeds/day was superior to other frequencies in respect of ERR, larval duration, larval weight, cocoon weight and shell weight. Frequency of 2 feeds a day was inferior. A positive correlation existed between ERR, cocoon weight and other economic characters and higher frequency of feeding. Silkworms fed 4, 3 and 2 times a day showed a corresponding decrease in the economic characters.

Krishnaswami *et al.* (1980) studied the effect of under feeding on the growth and development of silkworm breeds namely PM, KA and NB_4D_2. Under feeding resulted in prolonged larval duration, reduced larval growth, heavy mortality and poor cocoon characters. Bivoltine silkworm breeds were more affected compared to multivoltine breeds.

The efficiency of each feed in feeding schedule of 4 feeds a day among silkworm breeds PM, NB_7 and NB_{18} and two hybrids PM x NB_{18} and NB_{18} x NB_7 has been investigated by Jolly *et al.* (1981) in three rearings. The optimum feeding frequency was 4 feeds/day and less than these were found to adversely affect the quantitative and qualitative characters. Of all the feeds the one at 10 PM was observed to be very essential. Missing of this feed affected all characters adversely. Though all the feeds were important, missing of feed at 10 AM was found less detrimental.

Restricted feeding of silkworms prolonged the larval duration and reduced the larval weight by 47 per cent under single feeding regime, whereas under 3 feedings regime the larval weight reduced to the tune of 13 per cent (Anon., 1983b). The larvae maintained under restricted feeding level when provided with normal 4 feedings/day recorded substantial improvement in various characters like ERR, shell weight and cocoon filament length. Larvae reared with 2-3 feeds/day during young-age followed by 4 feeds/day in latter instars improved the economic characters.

In a study at CSR&TI, Mysore it was found that out of the 3 feeding frequencies namely 2, 3 and 4 feedings/day with three methods of feeding viz., chopped leaves, whole leaves and shootlets offered to silkworm hybrid, NB_{18} x NB_7 upto third instar and 4 feeds is common for fourth instar onwards. The ERR was 63 per cent in 2 feeds/day and 75 per cent in both 3 as well as 4 feedings/day (Anon., 1986b). Application of chopped mulberry leaves to worms of Nistari breed upto second instar, alternated with shoot feeding till ripening resulted in higher ERR (96.96%) compared to 95.51 per cent with that of whole leaves fed from third instar onwards.

Feeding schedule of 3 feeds/day in young-age followed by 4 feeds/day in late-age silkworm rearing was as good as 4 feeds/day throughout the larval period. The ERR for 10,000 worms brushed was highest in both number and weight in PM x NB_{18} (7118 ; 11.57 kg) and NB_{18} x NB_7 (7095 ; 11.91 kg) with 3 feeds/day in young silkworm rearing followed by 4 feeds/day in late-age (Anon., 1987b).

He *et al.* (1987) reported that silkworms fed 2 or 3 times daily had lower cocoon and shell weights compared with those fed 4 times daily but labour saving was 50 and 25 per cent, respectively when compared with the latter.

When the number of feeds was restricted from 8 to 1/day, it resulted in extension of larval period, but the pupal duration remained constant in all frequencies of feeding (Haniffa *et al.*, 1988). Those worms supplied with one feed/day suffered heavy mortality. Increase in number of feeds i.e., 4, 6 and 8 feeds/day enhanced larval weight, rate of feeding, assimilation, metabolism and conversion. It also produced higher values in weight, length and diameter of cocoons. Restricted number of feeds resulted in delayed onset of oviposition and reduced fecundity. Maximum larval weight of 3.49g was noticed for the first instar larvae belonging to 8 feeds/day and it decreased to 2.87mg in case of 2 feeds/day.

A study at CSR&TI, Mysore (Anon., 1989) revealed that silkworms provided with 3 feedings/day at 6 AM, 12 Noon and 6 PM gave cocoon yield of 43.52 kg/100 dfls which accounted for an increase of about 4.075kg and Rs.164.75/100 dfls when compared to control.

As per Karaivanov (1990) from Bulgaria, a decrease in the frequency rate of feeding at one or two feeds daily brought about certain decrease in cocoon and shell weights in silkworm hybrid, Shunrei x Shungetsu. A strong negative effect occurred with reduced frequency rate of feeding at the beginning of the fourth instar. The remaining indices viz., length of larval development, silkworm survival rate, cocoon silkness, cocoon yield, length of cocoon filament and consumption of mulberry leaves were slightly affected by the frequency of feeding. In view of the extent of labour consumption on repeated feeding and of the results obtained it was inferred that a two time daily supply of feed at the fifth instar could be successfully applied in silkworm rearing.

Das *et al.* (1991) revealed that fifth instar bivoltine silkworms could be fed twice daily without considerable deterioration of the economic characters of cocoons provided that the quantity of leaf required for four feedings was supplied in two equal halves and the freshness of the supplied leaves was maintained with optimum humidity of the rearing bed.

Non-significant differences existed between 2 and 4 feedings/day with number of good cocoons harvested, weight of good cocoons, yield/100 dfls, ERR by number and weight, absolute silk content and filament length but weight of 10 mature larvae, cocoon weight, shell weight and shell ratio were significantly higher in the 4 times feeding over the twice feeding and the per cent increase was 3.87, 4.0, 7.9 and 3.58, respectively, while the larval period was increased by one day in the twice feeding group (Das *et al.*, 1994).

A study at CSR&TI, Mysore (Anon, 1994) revealed non-significant differences between the feeding frequencies (2, 3 and 4 feeds/day) with shoot feeding. If sufficient quantity of shoots are supplied, even 2 feedings per day will not affect the rearing performance and further, considerable mandays can be saved.

The study at KSSR&DI, Thalaghattapura revealed that feeding the late-age silkworms with shoots twice a day was feasible than single feeding where final weight of larvae suffered significantly (1.38g) compared to control (1.58g) (Anon., 1997). One/two feeds with shoots performed better over leaf feeding and the variation in performance between shoot and leaf feeding is reduced to minimum with two feedings system compared to single feeding (Anon., 1998).

The impact of feeding schedule based on feeding potential in late-age larvae of $PMxNB_4D_2$ revealed that mulberry shoot feeding with a frequency of 2, 3, 4, 3, 2 and 3, 3, 4, 5, 5, 4, 3 feeds on the respective day of fourth and fifth instars, respectively yielded better results with respect to fifth instar larval duration and mature larval weight (Chandrashekar *et al.*, 1999a). Similarly, these frequencies during fourth and fifth instars recorded higher cocoon traits viz., cocoon weight, pupal weight, shell weight and shell ratio (Chandrashekar *et al.*, 1999b).

It is clear from the review that the number of feeds affects the performance of silkworm. The quantity of food and the nutritional quality or freshness of the leaves provided are to be maintained. It is very essential that the leaves should remain nutritionally acceptable to the larvae for their proper growth and development.

2.6 INFLUENCE OF NITROGEN LEVELS ON THE ECONOMICS OF MULBERRY PRODUCTION

The performance of sericulture industry is reflected by the cost of production of mulberry leaves and silk cocoons, in which production of quality mulberry leaves forms the major component in the cost of production of cocoons. Further, the high cost involved in silkworm rearing necessitates to think of effective method of harvesting, preparing and application of mulberry to worms to reduce the cost of production without affecting productivity.

The experiment conducted at CSR&TI, Mysore (Anon., 1973d) indicated that the cost of production of mulberry leaves was minimum with the application of N @ 100 kg/ha/yr (18.8 paise/kg leaf) as compared to control (22.9 paise) with no fertilizer application.

The benefit-cost ratio for different levels of N was worked out at CSR&TI, Mysore (Anon., 1976c). With application of N @ 300 kg/ha/yr the cost of leaf production was the least (9.7 paise) and income per rupee spent on fertilizer was the highest (Rs.13.70) over other levels tried.

Benefit-cost ratio of individual levels of N (100, 300, 600 and 900 kg/ha/yr) has revealed that, application of N @ 300 kg/ha/yr gave mulberry leaf yield of 37,288 kg/ha/yr with cost of production for one kg leaf being 23 paise and additional income per rupee spent over fertilizer was Rs.9.60 and the response per kg of N was 77 kg of leaf (Kasiviswanathan *et al.*, 1979).

Economics of N fertilization was worked out at RSRS, Pampore at varied levels. Application of N @ 400 kg/ha/yr to mulberry yielded net returns of Rs.946.85 per hectare, followed by 300kg/ha/yr (Rs.76.84), while at 200 and 100 kg/ha/yr resulted in loss of Rs.427.42 and 614.13, respectively per hectare (Anon., 1984c).

Similar study was conducted by Fotedar *et al.* (1988), application of N @ 400 kg/ha/yr recorded net returns of more than two and a half fold (Rs.3,929.86/ha) over 100 kg/ha/yr.

Rajanna and Dandin (1993) observed that increased N level (450 kg/ha/yr) reduced the cost of production of mulberry leaf (Rs.0.62/kg) resulting in maximum cocoon production (1,617 kg/ha/yr) and highest net income of Rs.45,365/ha/yr, which is about 28 per cent more as compared to 300 kg N/ha/yr (Rs.0.69/kg, Rs.1,386 and Rs.35,333/ha/yr). Further, highest production cost of leaf (Rs.0.81/kg), lower cocoon production (1,138 kg/ha/yr) and inturn lower net income (Rs.24,503/ha/yr) were obtained at 150 kg N/ha/yr, which is about 30 per cent less as compared to 300 kg N/ha/yr.

Raje Gowda *et al.* (1999b) reported that the economic returns per rupee invested was higher with the application of $N+K_2SO_4$ @ 400:180 kg/ha/yr in respect of Pure Mysore (2.57:1) and 300:120 kg/ha/yr in case of NB_4D_2 (4.76:1) over other levels of N and K_2SO_4.

It is evident from the above literature that application of higher doses of N helps in reducing the cost of production of mulberry with higher returns over lower doses.

2.7 INFLUENCE OF METHODS AND FREQUENCIES OF FEEDING ON THE ECONOMICS OF COOON PRODUCTION

As per Yokoyama (1962b), the quantity of mulberry leaves required in the form of chopped leaves was higher as compared to that of the entire leaves, which inturn was higher than that of the chopped shoots and the entire shoots. The labour requirement for rearing could be reduced by about 20 per cent by feeding silkworms with shoots during fourth and fifth instars.

Rearing of silkworms after third moult in an open and simple rearing place by applying mulberry shoots reduced the quantity of mulberry leaves required for rearing silkworms by about 10 per cent and saved labour to the tune of about 30 per cent (Anon., 1972).

Harvesting of mulberry shoots was suggested (Anon., 1975d) as one of the best methods for rearing grown up larvae and it could save the labour cost on harvesting of mulberry leaves.

Siddappaji *et al.* (1983) observed that crop losses were low under shoot application and this method was economical as it reduced the cost of production compared to leaf feeding. Providing shoots, though traditionally accepted, was an alternative to leaf feeding in modern sericulture technology.

Chikkavenkateshappa (1987) found that mulberry leaf requirement, silk cocoon yield and the related cost of production varied to a considerable extent under different methods of application of mulberry leaves to silkworm hybrid, PM x NB_4D_2 from third instar onwards. The benefit-cost ratio was higher in the case of whole shoots without tender flush during post-rainy (2.33:1) and rainy (0.910:1) seasons, while the ratio was low in case of the chopped leaves (0.920:1 and 0.060:1, respectively).

Narasimhamurthy and Subramanyam (1988) observed non-significant differences between leaf feeding and shoot feeding for cocoon characteristics. While the consumption of leaf and labour with shoot feeding was lower compared to leaf feeding and it further reduces the leaf-cocoon ratio which helps to bring down the cost of production of cocoons.

Muraleedhara (1990) observed higher benefit-cost ratio (4.58:1) in case of silkworms reared on the whole mulberry shoots with tender flush applied throughout as compared to whole leaves cut into two bits (0.47:1) and check (1.61:1).

Kumar and Benchamin (1990) and Shekharappa *et al.* (1991) found that rearing of late-age silkworms by adopting shoot feeding method reduced cost of production of cocoons by Rs.15-20 per kg of cocoons over the leaf feeding method. In addition, about 10-15 per cent of extra brushing could be taken per unit plot because of leaf saving through better leaf quality maintenance during preservation and in the rearing seat. Further, the labour dependent risk was also significantly reduced and increased the profit margin by Rs.8,000 to 10,000 acre/ha/yr.

Das *et al.* (1994) opined that feeding silkworm twice a day was more economical than 4 feeds/day besides saving considerable time and the commercial rearers can utilize the time in their household activity or for better maintenance of their mulberry fields or other cash crops.

Chandrappa *et al.* (1999) through survey found that the total cost of cocoon production with shoot feeding method per crop of 500 dfls was Rs.17,848 of which the cost of building and equipments was Rs.1,929 and the expenditure on silkworm rearing was Rs.15,918. Of the total rearing cost, the cost on leaf production was maximum (Rs.9,200), followed by labour (Rs.3,010) and young silkworm rearing (Rs.1,800). Thus the rearers by investing Rs.67.35 per kg for cocoon production have realised a net return of Rs.55.10 and the rate of return was Rs.1.82 for every rupee invested.

The above review suggests that application of mulberry leaves to silkworm in the form of shoots from first to final instar with 2-3 feeds per day reduces the cost of production of cocoons and fetches higher returns.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Studies were carried out on the "Effect of nitrogen levels on yield and quality of rainfed mulberry in relation to performance of silkworm with different methods and regimes of feeding" during 1998-2000 at Department of Sericulture in collaboration with the Departments of Soil Science and Agricultural Chemistry and Bio-Chemistry, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bangalore. The methods followed and materials used in the study are presented below under different headings.

3.1 EFFICACY OF NITROGENOUS FERTILIZER SOURCES ON PERFORMANCE OF RAINFED MULBERRY AND SILKWORM

3.1.1 MULBERRY CULTIVATION

3.1.1.1 Location of the experiment

The mulberry field of Department of Sericulture, UAS, GKVK, Bangalore is located at latitude of 12^0 58' N, longitude of 77^0 35' E and altitude of 930 m above mean sea level.

3.1.1.2 Soil type and characteristics

The soil of the experimental plot was red sandy loam. Composite soil samples were drawn at 0 to 45 cm depth prior to imposing the treatments and analysed for physical and chemical properties. The procedure followed for the analysis and the results of the same are presented in Table-3.1.

3.1.1.3 Climatic condition

The weekly weather data on maximum and minimum temperature (^{0}C), relative humidity during morning and noon (%), total rainfall (mm), wind velocity (km/hr), sunshine (hr) and evaporation (mm/day) prevailed at the experimental site during the crop growth period were compiled and are presented in Appendix-I.

3.1.1.4 Mulberry crop

The experiment was conducted in 12 year old rainfed M_5 mulberry garden with spacing of 0.9m x 0.9m gross plot of 5x4m and net plot of 4.5 x 3.6 m with 20 plants per plot. Prior to commencement of the experiment, the soil was brought into homogenous condition as for as possible by raising the crop without applying manures and fertilizers.

3.1.1.5 Experimental details

The mulberry crop selected for the experiment was bottom pruned during first week of July 1998 and farm yard manure (FYM) was applied to the plots @ 10 t/ha and mixed thoroughly. The experiment consisted of soil application of different sources of nitrogenous fertilizers 100 kg/ha/year viz.,

T_1 = Urea
T_2 = Calcium ammonium nitrate (CAN)
T_3 = Ammonium chloride
T_4 = Ammonium sulphate
T_5= Control.

While phosphorus and potassium were applied in the form of single super phosphate and muriate of potash @ 50 kg/ha/year, the control was maintained by applying required FYM, phosphorus and potassium. The cultural practices were as per the recommended package of practices (Krishnaswami, 1978a).

3.1.1.6 Experimental design

The experiment was laid out in a Randomized Complete Block Design and the five treatments were replicated five times.

3.1.1.7 Observations recorded

Yield parameters

3.1.1.7.1 Leaf yield per plant

Leaf yield (g) was recorded replication-wise by harvesting fresh leaves from 10 randomly selected plants under each treatment and the mean yield was calculated.

3.1.1.7.2 Leaf yield per ha per year

The leaf yield kg/ha/year was calculated based on the leaf yield/plant.

Foliar constituents of mulberry

Collection of leaf samples

The leaf samples were collected after 60 days of treatment imposition at three different heights of the plant viz., top, middle and bottom leaves in paper bags and composite leaf samples were made. Leaves were shade dried for three days and then dried in hot air oven at 70°C until constant weight was obtained. The dried leaf samples were ground into fine powder and preserved in butter paper bags for chemical analysis. Each sample had five replications.

Quality parameters

3.1.1.7.3 Leaf Moisture

Moisture content of the leaf was estimated through gravimetric method by taking the difference between fresh and dry weights and expressed in percentage on fresh weight basis (A.O.A.C., 1970).

$$\text{Moisture (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.1.1.7.4 Chlorophyll

Chlorophyll content of the leaf was estimated by following the procedure outlined by Hiscox and Israelstam (1979) at the wavelength of 645 and 663 nm using a spectrophotometer.

The chlorophyll a, b and total chlorophyll were computed using the suggested formulae (Arnon, 1949).

Chlorophyll 'a'

mg/g fresh weight = 12.7 (O.D. 663) – 2.69 (O.D. 645) x V/1000 x W where, O. D. = Optical difference

V = Volume made up (ml)

W = Weight of leaf sample (g)

Chlorophyll 'b'

mg/g fresh weight = 22.9 (O.D. 645) – 4.68 (O.D. 663) x V/1000 x W

Total Chlorophyll

mg/g fresh weight = 20.2 (O.D. 645) + 8.02 (O.D. 663) x V/1000 x W

3.1.1.7.5 Estimation of total Carbohydrates

The total carbohydrate content of the leaf was estimated following the procedure of Dubios *et al.* (1956) and expressed in percentage on oven dry weight basis.

3.1.1.7.6 Estimation of Crude protein

Crude protein content of the leaf was estimated by determining total nitrogen content in 0.5g sample by Micro-Kjeldhal's method. The crude protein was calculated by multiplying the per cent nitrogen of the sample with a factor 6.25 (A.O.A.C., 1970).

Elemental composition

3.1.1.7.7 Estimation of Nitrogen

A sample of 0.5g of leaf sample was digested in con. H_2SO_4 with K_2SO_4 + $CuSO_4$ + Se mixture as catalyst by Kjeldhal flask and distilled in an alkaline medium. The liberated ammonia was collected in four per cent boric acid containing bromocresol green methyl red mixed indicator and titrated against standard H_2SO_4. From the data the per cent nitrogen was calculated on oven dry weight basis (Jackson, 1973).

Digestion of leaf samples and extraction

Leaf samples of 0.5g were digested using triacid mixture (HNO_3 : $HClO_4$: H_2SO_4 at 10:4:1) as described by Jackson (1973), the digest was extracted with 6N HCl and volume made upto 100 ml and the extract was used for elemental analysis.

3.1.1.7.8 Estimation of Phosphorus

Phosphorus was determined in an aliquot of the plant extract by the Vanadomolybdate yellow colour method in HNO_3 medium. The colour intensity was measured in a spectrophotometer at 420 nm as described by Jackson (1973) and the phosphorus was expressed in percentage on oven dry weight basis.

3.1.1.7.9 Estimation of Potassium

The potassium content in the digested extract was determined using flame photometer and was expressed in percentage on oven dry weight basis (Jackson, 1973).

3.1.1.7.10 Estimation of Calcium and Magnesium

In the digested extract, calcium and magnesium were determined by titrating the aliquot against standard E.D.T.A. solution using suitable indicators as described by Jackson (1973) and the contents were expressed in percentage on oven dry weight basis.

3.1.1.7.11 Estimation of Sulphur

Sulphur content in digested sample was estimated by turbidometric method and expressed in percentage on oven dry weight basis (Jackson, 1973).

3.1.2 SILKWORM REARING PRACTICES

3.1.2.1 Disinfection of rearing room and equipments

One week prior to commencement of silkworm rearing, the rearing room along with rearing appliances were cleaned, washed thoroughly and disinfected properly with five per cent bleaching powder solution. The disinfection was done for the second time with four per cent formalin @ 800ml/ $10m^2$ (Krishnaswami *et al.*, 1973) and the rearing room was kept closed for 36 hours for effective disinfection.

3.1.2.2 Procurement of disease free layings (DFLs)

Disease free layings of bivoltine silkworm breed NB_4D_2 were procured from National Silkworm Seed Project, Central Silk Board. Bangalore. Before incubation they were surface disinfected with two per cent formalin for five minutes and washed in tap water and then the washed eggs were dried under shade to ensure disease for condition.

3.1.2.3 Incubation of DFLs

Layings were incubated at room temperature of 25-27^{0}C and relative humidity of 75-80 per cent in a rearing tray, provided with paraffin paper at the bottom and wet foam rubber strip all along its edges. Another paraffin paper was used to cover the tray to maintain required temperature and relative humidity. Layings were block boxed two days before hatching for simultaneous hatching. Then the layings were exposed to diffused light to obtain uniform hatching.

3.1.2.4 Brushing

After two hours of hatching, the larvae were offered with tender leaves of different treatments, under each replication separately and transferred on to the rearing trays with respective mulberry leaves.

3.1.2.5 Silkworm rearing

Silkworm feeding trials were conducted using bivoltine silkworm breed NB_4D_2 from first week of September 1998. The leaves grown under different treatments were fed to silkworms from brushing to ripening. One hundred worms were maintained in each replication of every treatment. The package of practices for silkworm rearing were carried out as per recommendation (Krishnaswami, 1978b). Weekly mean of temperature and relative humidity in rearing room is presented in Appendix-II.

3.1.2.6 Mounting and harvesting

The ripened silkworms were picked up from the rearing trays and transferred to mountages replication-wise under each treatment for spinning cocoons. The silk cocoons were harvested on fifth day of mounting.

3.1.2.6 Observations recorded

Rearing parameters

3.1.2.7.1 Larval weight (g)

Ten randomly selected larvae were weighed just before moulting/spinning during different instars under each treatment and replication-wise.

3.1.2.7.2 Larval duration (days)

The larval duration of each instar was obtained by adding feeding and moulting duration. The total larval duration was obtained by adding the duration of each instar in different treatments and replication-wise.

3.1.2.7.3 Larval survival (%)

It was calculated by using the formula given below and expressed in terms of percentage.

$$\text{Larval survival (\%)} = \frac{\text{Number of worms in the succeeding instar/spinning}}{\text{Number of worms in the beginning of instar}} \times 100$$

3.1.2.7.4 Effective rate of rearing (ERR) (%)

ERR was calculated using the formula :

$$ERR = \frac{\text{Number of cocoons harvested}}{\text{Number of larvae brushed}} \times 100$$

3.1.2.7.5 Cocoon yield (kg)/box of 50 DFLs

Cocoon yield was calculated using the formula :

$$CY = \frac{CYR \times EH \times 20000}{NLR}$$

Where,
CY = Cocoon yield (kg)
CYR = Cocoon yield in one replication (g)
EH = Egg hatching percentage/100
NLR = Number of larvae per replication

3.1.2.7.6 Silk productivity (cg/day)

The silk productivity was calculated using the formula :

$$\text{Silk productivity (cg/day)} = \frac{\text{Shell weight (cg)}}{\text{Fifth instar duration (days)}}$$

Cocoon parameters

3.1.2.7.7 Cocoon weight (g)

Ten cocoons were randomly selected from each treatment, replication-wise and the mean cocoon weight was computed.

3.1.2.7.8 Shell weight (g)

After removing the pupal and larval exuvium from the cocoons, the shell weight was recorded.

3.1.2.7.9 Shell ratio (%)

The shell ratio was calculated using the formula :

$$\text{Shell ratio (\%)} = \frac{\text{Shell weight (g)}}{\text{Cocoon weight (g)}} \times 100$$

3.1.2.7.10 Single cocoon filament length (m)

Five cocoons were randomly selected from each replication in different treatments were reeled to find out the filament length of the cocoon using epprouvette and it was determined by adopting the formula : $L = R \times 1.125$

Where : L = Filament length

R = Number of revolutions recorded by epprouvette

1.125 = Circumference of epprouvette in metres

3.1.2.7.11 Denier

The raw silk filament reeled with the epprouvette was dried in oven at 70 to 80°C and denier was determined by using the standard formula:

$$\text{Denier} = \frac{\text{Weight of single cocoon filament (g)}}{\text{Length of single cocoon filament (m)}} \times 9000$$

3.1.2.7.12 Estimation of Fibroin and Sericin

The cocoon shell was treated with two per cent KOH at 70-80°C for few minutes, constantly stirring till the cocoon became pluffy. The pluffy material was then washed thoroughly in tap water and further treated with diluted acetic acid (1g/litre) to neutralize the alkalinity. After another thorough wash in water the pluffy was dried at 90-100°C in hot air oven. The weight of fibroin thus obtained after dissolution of sericin was recorded. The fibroin and sericin contents in cocoon shell were calculated using the formulae :

$$\text{Fibroin (\%)} = \frac{\text{Weight of fibroin (g)}}{\text{Weight of cocoon shell (g)}} \times 100$$

Sericin (%) = 100 - Fibroin (%)

Grainage parameters

3.1.2.7.13 Rate of pupation (%)

Pupation rate was calculated by using the formula :

$$\text{Rate of pupation (\%)} = \frac{\text{Number of larvae pupated}}{\text{Number of larvae spun cocoon}} \times 100$$

3.1.2.7.14 Pupal weight (g)

Weight of 10 pupae from the already weighed cocoons was recorded in all the treatments, replication-wise.

3.1.2.7.15 Pupal duration (days)

Pupal duration was calculated from the time the worms stopped spinning until the time of emergence of moths.

3.1.2.7.16 Rate of moth emergence (%)

Moth emergence percentage was calculated based on the number of pupae transformed into adults and was computed using the formula :

$$\text{Rate of moth emergence(\%)} = \frac{\text{Number of moths emerged}}{\text{Number of pupae kept for moth emergence}} \times 100$$

3.1.2.7.17 Fecundity (eggs/laying)

The emerged male and female moths were allowed to mate in wooden trays. Males were separated from females after ensuring three hours of mating. Then five gravid female moths covered individually with cellules were allowed on to egg cards in the dark room for oviposition. The eggs laid by individual female were counted and recorded separately treatment and replication-wise. The freshly laid eggs were subjected to acid treatment within 20 hr of oviposition.

Acid treatment

The layings were first dipped in two percent formalin for surface disinfection and proper adhering of eggs and then they were washed and dipped in HCl of 1.071 specific gravity maintained at 46.1°C for 4-5 minutes. The layings were then washed, dried and kept for incubation.

3.1.2.7.18 Hatchability (%)

Five dfls from each of the treatment, replication-wise after acid treatment were incubated at room temperature for hatching. Black-boxing was done two days prior to hatching. It was calculated by using the formula:

$$\text{Hatchability (\%)} = \frac{\text{Number of eggs hatched}}{\text{Total number of eggs/laying}} \times 100$$

3.1.2.8 Statistical analysis of the data

The data in percentage were subjected to angular transformation (Snedecor and Cochran, 1979).

Data recorded on mulberry and silkworm were analysed statistically (one-way RCBD and CRD, respectively) for test of significance using Fisher's method of "Analysis of variance" as outlined by Sundarraj *et al.* (1972). The level of significance of 'F-test' was tested at 5 per cent.

Based on the information obtained from the preliminary studies with regard to the efficacy of different nitrogenous fertilizer sources viz., Urea, CAN Ammonium chloride and Ammonium sulphate on performance of rainfed mulberry and the silkworm, the CAN was selected as the source of N for further studies as it was found superior over other sources with regard to yield and quality of mulberry and larval, cocoon and grainage parameters of silkworm.

3.2 EFFECT OF DIFFERENT LEVELS OF NITROGEN SUPPLIED THROUGH CAN ON RAINFED MULBERRY AND ITS INFLUENCE ON SILKWORM THROUGH DIFFERENT METHODS AND FREQUENCIES OF FEEDING

3.2.1 NITROGEN LEVELS ON MULBERRY

The detailed methodology, materials used and observations recorded on mulberry are same as under 3.1.1.

The results on soil analysis are presented in Table-3.1 and weather parameters during crop growth growth period are detailed in Appendix-I. The mulberry crop was bottom pruned during first week of July 1999 and three levels of N viz., N_1 = 75 kg/ha/year, N_2 = 100 kg/ha/year and N_3 = 125 kg/ha/year were applied to soil through CAN. There were three replications for each treatment. While the application of FYM, P and K was followed as per recommended package.

3.2.2 METHODS OF FEEDING SILKWORM

The rearing techniques was similar as under 3.1.2.

Three methods of feeding silkworm viz., M_1 = Whole leaves (Plate 3.1a), M_2 = Whole shoots (Plate 3.1b) and M_3 = Chopped shoots and these methods were tired in three replications.

Table 3.1: Physical and chemical properties of soil at experimental site, Department of Sericulture, UAS, GKVK, Bangalore

Particulars		Before the experimentation of		Method
		Nitrogen sources	Nitrogen levels	
A. Physical properties (Oven dry basis)				
1	Coarse sand (%)	40.23	41.22	International pipette method
2	Fine sand (%)	36.35	36.12	(Piper, 1966)
3	Silt (%)	13.15	12.58	
4	Clay (%)	10.0	9.78	
B. Chemical properties				
1	Soil pH	5.95	5.90	Potentiometry (Jackson, 1973)
2	Electrical conductivity (dms/cm^2 at 25^{0}C)	0.29	0.30	Conductivity Bridge (Jackson, 1973)
3	Organic Carbon (%)	0.50	0.52	Walkely and Black wet oxidation method (Jackson, 1973)
4	Available Nitrogen (kg/ha)	298.5	295.4	Alkaline permanganate method (Jackson, 1973)
5	Available Phosphorus (kg/ha)	23.25	24.15	Bray's method (Jackson, 1973)
6	Available Potassium (kg/ha)	212.5	211.9	Flame photometer (Jackson, 1973)

Plate 3.1: Methods of feeding silkworms

a. Whole leaves

b. Whole shoots

3.2.3 FREQUENCY OF FEEDING SILKWORM

The rearing technique remained similar to that of 3.1.2.

Three frequencies of feeding silkworm viz., F_1 = 3 feeds/day (6AM, 2PM, 10PM), F_2 = 4 feeds/day (6AM, 11AM, 5PM, 10PM), F_3 = 5 feeds/day (6AM,10AM, 2PM, 6PM, 10PM) and the frequencies were tried in three replications.

3.2.4 INTERACTION OF NITROGEN LEVELS, FEEDING METHODS AND FREQUENCIES ON SILKWORM

The combination of N levels, feeding methods and frequencies are detailed below.

T_1 = N @ 75 kg/ha/yr + whole leaves + 3 feeds/day
T_2 = N @ 75 kg/ha/yr + whole leaves + 4 feeds/day
T_3 = N @ 75 kg/ha/yr + whole leaves + 5 feeds/day
T_4 = N @ 75 kg/ha/yr + whole shoots + 3 feeds/day
T_5 = N @ 75 kg/ha/yr + whole shoots + 4 feeds/day
T_6 = N @ 75 kg/ha/yr + whole shoots + 5 feeds/day
T_7 = N @ 75 kg/ha/yr + chopped shoots + 3 feeds/day
T_8 = N @ 75 kg/ha/yr + chopped shoots + 4 feeds/day
T_9 = N @ 75 kg/ha/yr + chopped shoots + 5 feeds/day
T_{10} = N @ 100 kg/ha/yr + whole leaves + 3 feeds/day
T_{11} = N @ 100 kg/ha/yr + whole leaves + 4 feeds/day
T_{12} = N @ 100 kg/ha/yr + whole leaves + 5 feeds/day
T_{13} = N @ 100 kg/ha/yr + whole shoots + 3 feeds/day
T_{14} = N @ 100 kg/ha/yr + whole shoots + 4 feeds/day
T_{15} = N @ 100 kg/ha/yr + whole shoots + 5 feeds/day
T_{16} = N @ 100 kg/ha/yr + chopped shoots + 3 feeds/day

T_{17} = N @ 100 kg/ha/yr + chopped shoots + 4 feeds/day

T_{18} = N @ 100 kg/ha/yr + chopped shoots + 5 feeds/day

T_{19} = N @ 125 kg/ha/yr + whole leaves + 3 feeds/day

T_{20} = N @ 125 kg/ha/yr + whole leaves + 4 feeds/day

T_{21} = N @ 125 kg/ha/yr + whole leaves + 5 feeds/day

T_{22} = N @ 125 kg/ha/yr + whole shoots + 3 feeds/day

T_{23} = N @ 125 kg/ha/yr + whole shoots + 4 feeds/day

T_{24} = N @ 125 kg/ha/yr + whole shoots + 5 feeds/day

T_{25} = N @ 125 kg/ha/yr + chopped shoots + 3 feeds/day

T_{26} = N @ 125 kg/ha/yr + chopped shoots + 4 feeds/day

T_{27} = N @ 125 kg/ha/yr + chopped shoots + 5 feeds/day

The above combinations of treatments were tried in three replications and the observations (average of two rearings - September, 1999 and January, 2000) recorded as under 3.1.2. Temperature and relative humidity of the rearing room (weekly-wise) was recorded and presented in Appendix-II.

3.2.5 CORRELATION STUDIES

In order to know the relationship between foliar constituents of mulberry at varied levels of N with larval, cocoon and grainage parameters, the correlation co-efficients were worked out at P=0.05 as per procedure outlined by Snedecor and Cochran (1979).

3.2.6 ECONOMICS OF RAINFED MULBERRY PRODUCTION WITH DIFFERENT NITROGEN (CAN) LEVELS

The cost of production of mulberry under different levels of N fertilization, mulberry yield and returns were worked out by taking the current prices for inputs and outputs as per the methodology outlined by Jolly (1986a).

3.2.7 ECONOMICS OF NITROGEN (CAN) LEVELS, FEEDING METHODS AND FREQUENCIES ON COCOON PRODUCTION

The economics of silk cocoon production with different levels of N supplied to mulberry, feeding methods and frequencies was worked out as per the procedure outlined by Muraleedhara (1990).

3.2.8 STATISTICAL ANALYSIS OF THE DATA

The data recorded on mulberry yield and foliar constituents with different levels of N applied to the crop were analysed through standard deviation method. The observations recorded on silkworm and economics of silk cocoon production with different levels of N, feeding methods and frequencies were analysed statistically (3-way CRD) as outlined by Sundarraj *et al.* (1972) at 5 per cent level of significance.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the experiments carried out on the "Effect of nitrogen levels on yield and quality of rainfed mulberry in relation to performance of silkworm with different methods and regimes of feeding" at UAS, Bangalore are presented below.

4.1 INFLUENCE OF NITROGENOUS SOURCES ON THE PERFORMANCE OF RAINFED MULBERRY

The data on the effect of different sources of nitrogenous fertilizers on yield, quality and elemental composition of M_5 mulberry under rainfed conditions are presented in Table 4.1 and 4.2.

4.1.1 YIELD PARAMETERS

4.1.1.1 Leaf yield (kg/10 plants)

The mulberry leaf yield differed significantly due to nitrogenous fertilizer sources, highest being with calcium ammonium nitrate (CAN) (2.407 kg), urea (2.273 kg), ammonium chloride (2.206 kg) and ammonium sulphate (2.130 kg). However, the yield was lowest in control (1.512 kg).

4.1.1.2 Leaf yield (kg/ha/year)

Mulberry receiving N through CAN gave significantly higher leaf yield of 14,440 kg. The crop that received N through urea (13,638 kg), ammonium chloride (13,236 kg) and ammonium sulphate (12,780 kg) produced moderate yield and it was least in control (9,072 kg) (Table 4.1).

4.1.2 QUALITY PARAMETERS

4.1.2.1 Leaf moisture

Application of different nitrogenous fertilizers had increased the leaf moisture over control (Table 4.1). Leaf moisture was significantly higher in respect of urea (73.82%), CAN (72.41%), ammonium sulphate (71.92%) and ammonium chloride (71.53%) and least in respect of control (69.03%).

4.1.2.2 Chlorophyll

The effect of different sources of nitrogenous fertilizers on chlorophyll 'a', 'b' and total chlorophyll contents of mulberry leaves was significant. The plots which received CAN registered higher chlorophyll 'a' (1.726 mg/g), 'b' (0.958 mg/g) and total chlorophyll (2.684 mg/g), followed by urea (1.691, 0.931 and 2.622 mg/g), ammonium chloride (1.576, 0.772 and 2.348 mg/g), ammonium sulphate (1.549, 0.734 and 2.283 mg/g) and the same were less in control (1.335, 0.610 and 1.945 mg/g) (Table 4.1).

4.1.2.3 Total carbohydrates

Among the N sources, total carbohydrate content of leaf was highest with CAN (19.89%), urea (18.23%), ammonium chloride (17.84%) and ammonium sulphate (16.33%). However, the total carbohydrates were lowest (14.29%) in respect of control.

4.1.2.4 Crude protein

The crude protein content in mulberry leaves varied significantly among different nitrogenous sources, the highest being in CAN

Table 4.1: Effect of nitrogenous source fertilizers on yield and quality of M_5 mulberry leaf under rainfed condition

Sl. No.	Treatments	Leaf yield		Moisture (%)	Chlorophyll (mg/g)			Total carbohy-drates (%)	Crude protein (%)
		Kg/10 plants	Kg/ha/ Year		a	b	Total		
1	Urea	2.273	13,638	73.82 (59.30)	1.691	0.931	2.622	18.23 (25.21)	19.26 (25.97)
2	CAN	2.407	14,440	72.41 (58.38)	1.726	0.958	2.684	19.89 (26.43)	20.38 (26.74)
3	Ammonium chloride	2.206	13,236	71.53 (57.81)	1.576	0.772	2.348	17.84 (24.92)	20.12 (26.60)
4	Ammonium sulphate	2.130	12,780	71.92 (58.06)	1.549	0.734	2.283	16.33 (23.76)	18.08 (25.10)
5	Control	1.512	9,072	69.03 (56.24)	1.335	0.610	1.945	14.29 (22.11)	12.65 (20.71)
	S.Em ±	0.113	141.2	0.026	0.020	0.063	0.116	1.182	0.093
	C.D.at 5%	0.339	423.4	0.077	0.060	0.190	0.348	3.543	0.278

Figures in the parentheses are angular transformed values

(20.38%) and ammonium chloride (20.12%). Further, it was moderate with urea (19.26%) and ammonium sulphate (18.08%) and lowest for control (12.65%) (Table 4.1).

4.1.3 ELEMENTAL COMPOSITION

4.1.3.1 Nitrogen

The nitrogen content of mulberry leaf differed significantly among the nitrogenous fertilizers, CAN recording highest nitrogen (3.261%), followed by ammonium chloride (3.219%), urea (3.081%) and ammonium sulphate (2.892%). It was lowest with control (2.024%).

4.1.3.2 Phosphorus

The phosphorus content in mulberry leaves differed significantly with the use of different forms of N. Higher phosphorus content was noticed in CAN (0.594%) and urea (0.576%). However, phosphorus content was lower for control (0.410%).

4.1.3.3 Potassium

Marked differences were exhibited with regard to potassium content in mulberry leaves among different sources of N. Higher potassium content was found with CAN (2.193%), urea (2.162%), ammonium chloride (2.117%) and ammonium sulphate (2.021%), while it was least (1.943%) in check (Table 4.2).

Table 4.2: Effect of nitrogenous source fertilizers on elemental composition of rainfed M_5 mulberry leaf

Sl. No.	Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Sulphur (%)
1	Urea	3.081	0.576	2.162	2.997	0.663	0.282
		(10.04)	(4.199)	(8.337)	(9.865)	(4.552)	(2.931)
2	CAN	3.261	0.594	2.193	3.028	0.706	0.358
		(10.34)	(4.276)	(8.602)	(9.952)	(4.714)	(3.357)
3	Ammonium	3.219	0.495	2.117	2.795	0.624	0.313
	chloride	(10.27)	(3.825)	(8.243)	(9.546)	(4.399)	(3.114)
4	Ammonium	2.892	0.523	2.021	2.563	0.587	0.240
	sulphate	(9.717)	(3.961)	(8.040)	(9.122)	(4.246)	(2.649)
5	Control	2.024	0.410	1.943	1.582	0.513	0.191
		(8.047)	(3.303)	(7.416)	(7.023)	(3.914)	(2.458)
	S.Em ±	0.631	0.103	0.350	0.537	0.048	0.085
	C.D.at 5%	1.893	0.308	1.054	1.610	0.143	0.225

Figures in the parentheses are angular transformed values

4.1.3.4 Calcium

Calcium content in mulberry leaves was significantly influenced by sources of nitrogen. It was highest in respect of CAN (3.028%), urea (2.997%), ammonium chloride (2.795%) and ammonium sulphate (2.563%). But it was lowest in control (1.582%).

4.1.3.5 Magnesium

Magnesium content in mulberry leaves differed significantly among the nitrogenous sources tested. It was highest with CAN (0.706%), moderate among urea (0.663%), ammonium chloride (0.624%) and ammonium sulphate (0.587%) and lowest in control (0.513%).

4.1.3.6 Sulphur

Statistical variations were noticed in sulphur content of mulberry leaves raised under rainfed condition by supplying different nitrogenous sources, the highest being in case of CAN (0.358%). However, ammonium chloride (0.313%) and urea (0.282%) ammonium sulphate (0.240%) and control (0.191%) were on par with each other, the latter value being lower (Table 4.2).

4.2 INFLUENCE OF NITROGENOUS SOURCES ON THE PERFORMANCE OF SILKWORM

4.2.1 REARING PARAMETERS

The data on rearing parameters as influenced by the different sources on N are presented in Table 4.3.

4.2.1.1 Mature larval weight

Silkworms fed with mulberry leaf obtained by applying different sources of nitrogenous fertilizers greatly influenced the mature larval weight (Table 4.3). Significantly highest mature larval weight resulted in respect of CAN (41.52 g/10) and urea (40.97g). Further, larval weights recorded in respect of ammonium chloride (39.62g) and ammonium sulphate (39.49g) were found non-significant. However, lowest larval weight was associated with control (26.38g).

4.2.1.2 Total larval duration

Nitrogen sources did influence the total larval duration, shortest being with CAN (26.40 days), urea (27.00 days), ammonium chloride (27.25 days) and ammonium sulphate (27.50 days). Whereas, the duration was longest in respect of control (30.50 days).

4.2.1.3 Larval survival

The survival of larvae was higher when silkworms were fed with mulberry leaves grown with the application of CAN (94.60%) and urea (93.40%). However, it was least in control (79.00%).

4.2.1.4 Effective rate of rearing (ERR)

Marked differences existed among N sources in respect of ERR (Table 4.3). Highest being with CAN (91.40%) and urea (90.40%). The sources next in the order were ammonium chloride (88.20%) and ammonium sulphate (87.20%) and the same was lowest in control (70.40 %).

Table 4.3: Influence of fertilizer nitrogen sources applied to rainfed M_5 mulberry on rearing performance of *Bombyx mori* L.

Sl. No.	Treatments	Mature larval Weight (g/10)	Total larval duration (days)	Larval survival (%)	ERR (%)	Cocoon yield (kg/box of 50 DFLs)	Silk productivity (cg/day)
1	Urea	40.97	27.00	93.40 (75.16)	90.40 (71.96)	35.62	5.041
2	CAN	41.52	26.40	94.60 (76.68)	91.40 (73.04)	36.75	5.298
3	Ammonium chloride	39.62	27.25	92.00 (73.85)	88.20 (69.96)	34.43	4.734
4	Ammonium sulphate	39.49	27.50	92.40 (74.03)	87.20 (69.08)	33.72	4.684
5	Control	26.38	30.50	79.00 (62.74)	70.40 (57.05)	17.07	2.062
	S.Em ±	0.349	0.496	0.688	0.706	0.239	0.049
	C.D.at 5%	1.030	1.462	2.031	2.083	0.706	0.146

Figures in the parentheses are angular transformed values

4.2.1.5 Cocoon yield

Silkworms fed with mulberry leaves grown with different sources of nitrogenous fertilizers caused a significant variation with regard to cocoon yield. Yield was highest with CAN (36.75 kg/box of 50 dfls) and urea (35.62 kg). The sources ammonium chloride (34.43 kg) and ammonium sulphate (33.72 kg) were found next best with no tangible difference between them. Further, the silkworms fed with mulberry leaves raised without supplying N recorded lowest cocoon yield (17.07 kg).

4.2.1.6 Silk productivity

Silk productivity i.e., the unit weight of cocoon shell per day of fifth instar was highest on leaf corresponding to CAN (5.298 cg/day), urea (5.041 cg), ammonium chloride (4.734 cg) and ammonium sulphate (4.684 cg). However, the productivity was least in control (2.062 g) (Table 4.3),

4.2.2 COCOON PARAMETERS

The data on the effect of nitrogenous source fertilizers on cocoon parameters are presented in Table 4.4.

4.2.2.1 Cocoon weight

Cocoons spun by the worms fed on mulberry leaves obtained by fertilizing the crop with different sources of N had profound influence on cocoon weight, significantly higher cocoon weight being recorded in respect of CAN (21.31 g/10) and urea (21.04g). The sources ammonium chloride (20.93g) and ammonium sulphate (20.81g) remained on par were next best. However, the cocoon weight was lower in control (14.85g) (Table 4.4).

4.2.2.2 Shell weight

The shell weight too differed significantly when silkworms were fed with mulberry leaves obtained through different sources of nitrogenous fertilizers, highest being with CAN (4.450 g/10) and urea (4.285g). However, ammonium chloride (4.082g) and ammonium sulphate (4.051g) yielded moderate shell weight and were superior to control (2.052g).

4.2.2.3 Shell ratio

Silkworms fed with mulberry leaves obtained through application of CAN and urea produced the highest shell ratio of 20.88 and 20.37 per cent, respectively. The shell ratio for ammonium chloride (19.50%) and ammonium sulphate (19.47%) was almost equal but significantly higher than that of control (13.82%) (Table 4.4).

4.2.2.4 Single cocoon Filament length

Significant influence was exerted on single cocoon filament length by the sources of N. Longest filament was recorded in respect of leaf raised with CAN (1144m) and urea (1105m). The next best source was ammonium chloride (1076m). The cocoon filament was shortest in control (692m).

4.2.2.5 Denier

Though silkworms fed with mulberry leaves fertilized with different sources of nitrogenous fertilizers did not cause any

Table 4.4: Influence of fertilizer nitrogen sources applied to rainfed M_5 mulberry on cocoon parameters of *Bombyx mori* L.

Sl. No.	Treatments	Cocoon Weight (g/10)	Shell weight (g/10)	Shell ratio (%)	Single cocoon filament length (m)	Denier	Fibroin (%)	Sericin (%)
1	Urea	21.04	4.285	20.37 (26.83)	1105	2.46	77.42 (61.64)	21.52 (27.64)
2	CAN	21.31	4.450	20.88 (27.19)	1144	2.46	78.14 (62.14)	20.83 (27.15)
3	Ammonium chloride	20.93	4.082	19.50 (26.21)	1076	2.48	76.32 (60.89)	22.65 (28.42)
4	Ammonium sulphate	20.81	4.051	19.47 (26.18)	1023	2.52	75.06 (60.05)	23.91 (29.27)
5	Control	14.85	2.052	13.82 (21.82)	692	2.55	72.82 (58.59)	26.12 (30.74)
	S.Em ±	0.102	0.058	0.070	16.45	0.043	0.492	0.089
	C.D.at 5%	0.300	0.171	0.206	48.54	-	1.450	0.263

Figures in the parentheses are angular transformed values

significant variation in size of the single cocoon filament, it varied form 2.46 (CAN) to 2.55 (control) (Table 4.4).

4.2.2.6 Fibroin

Fibroin secretion varied among the batches of silkworms which received mulberry leaves grown under different nitrogenous source fertilizers (Table 4.4). The highest being with CAN (78.14%), urea (77.42%) and ammonium chloride (76.32%). It was lowest in control (72.82%).

4.2.2.7 Sericin

Similarly, the secretion of sericin did vary among the N sources. Lowest sericin content was registered with CAN (20.83%) and urea (21.52%). Ammonium chloride (22.65%) and ammonium sulphate (23.91%) stood next. Nevertheless, sericin content was highest in control (26.12%) (Table 4.4).

4.2.3 GRAINAGE PARAMETERS

The data on the influence of nitrogenous source fertilizers on grainage parameters are presented in Table 4.5.

4.2.3.1 Rate of pupation

Differences in rate of pupation were vivid among the nitrogenous sources. The highest pupation rate was registered with CAN (96.44%) and ammonium chloride (95.32%). Urea (93.40%) and ammonium sulphate (92.24%) caused similar effect on pupation rate. It was least of 80.40 per cent in respect of control (Table 4.5).

4.2.3.2 Pupal weight

Weight of pupae was non-significant among the nitrogenous sources tested on mulberry, which varied from 12.72 (control) to 16.79 g/10 pupae (ammonium chloride).

4.2.3.3 Pupal duration

The effect of N sources on pupal duration was statistically significant, shortest being with CAN (11.50 days), ammonium chloride (12.00 days) and urea (12.50 days). The duration was longest with ammonium sulphate (12.75 days) and control (13.75 days).

4.2.3.4 Rate of moth emergence

Significant differences were obvious with regard to moths emerged from pupae that resulted from feeding of worms with leaves grown under different nitrogenous source fertilizers (Table 4.5). As high as 96.48 per cent was recorded with CAN and 95.60 per cent with ammonium chloride. Urea (94.40%) and ammonium sulphate (93.52%) recorded moderate emergence with no tangible difference between them. However, control recorded lower rate of moth emergence (81.12%).

4.2.3.5 Fecundity

Fecundity was highest among moths emerged from pupae formed by worms nourished with leaves grown by the application of CAN (546.4 eggs/laying) and urea (533.5 eggs). Next best was ammonium chloride (511.5 eggs) which was comparable with ammonium sulphate (502.4 eggs). Significantly least fecundity was encountered in control (423.5 eggs).

Table 4.5: Influence of nitrogenous source fertilizers applied to rainfed M_5 mulberry on grainage traits of *Bombyx mori* L.

Sl. No.	Treatments	Rate of pupation (%)	Pupal weight (g/10)	Pupal duration (days)	Rate of moth emergence (%)	Fecundity (eggs/ Laying)	Hatchability (%)
1	Urea	93.40 (75.18)	16.69	12.50	94.40 (76.45)	533.5	93.43 (75.22)
2	CAN	96.44 (79.43)	16.30	11.50	96.48 (79.39)	546.4	94.31 (76.29)
3	Ammonium chloride	95.32 (77.69)	16.79	12.00	95.60 (78.05)	511.5	93.25 (75.02)
4	Ammonium sulphate	92.24 (73.89)	16.66	12.75	93.52 (75.34)	502.4	92.92 (74.65)
5	Control	80.40 (63.74)	12.72	13.75	81.12 (64.26)	423.5	80.13 (63.54)
	S.Em ±	0.927	0.281	0.379	0.907	7.045	0.743
	C.D.at 5%	2.736	0.837	1.118	2.675	20.78	2.192

Figures in the parentheses are angular transformed values

4.2.3.6 Hatchability

Though non-significant differences existed with regard to hatchability of eggs in respect of nitrogenous sources, higher hatchability was associated with CAN (94.31%), urea (93.43%), ammonium chloride (93.25%) and ammonium sulphate (92.92%), but control registered significantly lower hatching (80.13%) (Table 4.5).

Among the nitrogenous sources, CAN was adjudged as the best source based on yield and quality of M_5 mulberry and performance of silkworm (NB_4D_2) and hence different levels of N were supplied to mulberry and their effects along with methods of offering mulberry and frequencies of feeding were studied.

4.3 EFFECT OF NITROGEN (CAN) LEVELS ON THE PREFORMANCE OF RAINFED MULBERRY

The results on the yield, quality and elemental composition of rainfed M_5 mulberry as influenced by different levels of nitrogen are presented in Table 4.6 and 4.7.

4.3.1 YIELD PARAMETERS

4.3.1.1 Leaf yield (kg/10 plants)

Leaf yield increased considerably with increase in N fertilizer dose from 75 to 125 kg/ha/yr. Application of N @ 125 kg/ha/yr recorded higher leaf yield (2.494 ± 0.154 kg) than that of 100 (2.372 ± 0.148 kg) and 75 kg/ha/yr (2.131 ± 0.054 kg).

4.3.1.2 Leaf yield (kg/ha/year)

Varied levels of N had profound influence on the leaf yield of mulberry in that N @ 125 kg/ha/yr recorded highest yield of 14,964 ± 921.0 kg over 100 and 75 kg/ha/yr which recorded 14,234 ± 886.7 and 12,786 ± 322.3 kg, respectively (Table 4.6).

4.3.2 QUALITY PARMETERS

4.3.2.1 Leaf Moisture

Moisture content of leaf differed due to different levels of N applied to mulberry. It was highest with 125 kg/ha/yr (72.08 ± 0.400%), 100 (70.72 ± 1.196%) and 75 kg/ha/yr (68.95 ± 1.099%).

4.3.2.2 Chlorophyll

The leaves obtained by the application of N @ 125 kg/ha/yr recorded higher chlorophyll 'a' (1.748 ± 0.029 mg/g), chlorophyll 'b' 0.982 ± 0.012 mg/g) and total chlorophyll (2.730 ± 0.041 mg/g) as compared to 100 (1.718 ± 0.068, 0.940 ± 0.034, 2.658 ± 0.094 mg/g) and 75 kg/ha/yr (1.590 ± 0.080, 0.849 ± 0.024 and 2.439 ± 0.068 mg/g), respectively (Table 4.6).

4.3.2.3 Total carbohydrates

Levels of N had a marked influence on the total carbohydrate content of leaf, highest being at 125 kg/ha/yr (21.33 ± 0.478%), followed by 100 (19.96 ± 0.597%) and 75 kg/ha/yr (17.83 ± 0.902%).

Table 4.6: Effect of different levels of nitrogen (CAN) on yield and quality of M_5 mulberry leaf under rainfed condition

Sl. No.	Treatments	Leaf yield		Moisture (%)	Chlorophyll (mg/g)			Total carboh-ydrates (%)	Crude protein (%)
		Kg/10 plants	Kg/ha/year		a	b	Total		
1	N @ 75 kg/ha/year	2.131± 0.054	12,786± 322.3	68.95± 1.099	1.590± 0.080	0.849± 0.024	2.439± 0.068	17.83± 0.902	17.39± 0.453
2	N @ 100 kg/ha/year	2.372± 0.148	14,234± 886.7	70.72± 1.196	1.718± 0.068	0.940± 0.034	2.658± 0.094	19.96± 0.597	20.60± 0.951
3	N @ 125 kg/ha/year	2.494± 0.154	14,964± 921.0	72.08± 0.400	1.748± 0.029	0.982± 0.012	2.730± 0.041	21.33± 0.478	21.26± 0.345

4.3.2.4 Crude protein

Crude protein content in mulberry leaf varied to the maximum extent when the levels of N were considered. As high as 21.26 ± 0.345 per cent was recorded at 125 kg/ha/yr as compared to 100 (20.60 ± 0.951%) and 75 kg/ha/yr (17.39 ± 0.453%) (Table 4.6).

4.3.3 ELEMENTAL COMPOSITION

4.3.3.1 Nitrogen

Increase in levels of N applied inturn increased the N content of mulberry leaf. Higher nitrogen (3.403 ± 0.055%) was observed with 125 kg/ha/yr as compared to 100 (3.296 ± 0.153%) and 75 kg/ha/yr (2.783 ± 0.073%).

4.3.3.2 Phosphorus

Considerable variation was observed in respect of N levels with regard to the per cent phosphorus. Phosphorus content was highest when N was applied @ 125 kg/ha/yr (0.624 ± 0.018%), followed by 100 (0.590 ± 0.025%) and 75 kg/ha/yr (0.573 ± 0.020%) (Table 4.7).

4.3.3.3 Potassium

Potassium content differed moderately with the application of N at different levels. Higher percentage of potassium was found at 125 kg/ha/yr (2.314 ± 0.040%) over 100 (2.213 ± 0.028%) and 75 kg/ha/yr (2.104 ± 0.025%).

Table 4.7: Influence of varied levels of nitrogen (CAN) on elemental composition of M_5 mulberry leaf under rainfed condition

Sl. No.	Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Sulphur (%)
1	N @ 75 kg/ha/year	2.783± 0.073	0.573± 0.020	2.104± 0.025	2.613± 0.070	0.606± 0.026	0.260± 0.029
2	N @100 kg/ha/year	3.296± 0.153	0.590± 0.025	2.213± 0.028	2.863± 0.045	0.702± 0.029	0.344± 0.017
3	N @ 125 kg/ha/year	3.403± 0.055	0.624± 0.018	2.314± 0.040	2.985± 0.010	0.726± 0.017	0.359± 0.019

4.3.3.4 Calcium

Marked difference was seen in the calcium content of leaf among different levels of N, the higher content of calcium being found with leaf corresponding to 125 kg/ha/yr (2.985 ± 0.010%) and next in the order were 100 (2.863 ± 0.045%) and 75 kg/ha/yr (2.613 ± 0.070%) (Table 4.7).

4.3.3.5 Magnesium

Mulberry receiving N at different levels caused a considerable variation in respect of per cent magnesium. N supplied @ 125 kg/ha/yr registered higher content of magnesium (0.726 ± 0.017%) as compared to 100 (0.702 ± 0.029%) and 75 kg/ha/yr (0.606 ± 0.026%).

4.3.3.6 Sulphur

In respect of sulphur content also, variation was found at different levels of N supplied to mulberry. The highest sulphur content being with N @ 125 kg/ha/yr (0.359 ± 0.019%), followed by 100 (0.344 ± 0.017%) and less with 75 kg/ha/yr (0.260 ± 0.029%) (Table 4.7).

The above results revealed that the application of N @ 125 kg/ha/yr had a profound influence on the yield and quality of rainfed mulberry leaves over 100 and 75 kg/ha/yr.

4.4 INFLUENCE OF METHODS AND FREQUENCIES OF FEEDING RAINFED MULBERRY RAISED WITH DIFFERENT LEVELS OF NITROGEN (CAN) ON THE PERFORMANCE OF SILKWORM

4.4.1 REARING PARAMETERS

The data on rearing parameters viz., larval weight, larval duration, larval survival, ERR, cocoon yield and silk productivity as influenced by feeding silkworms with leaves raised at varied levels of N through different methods and frequencies are presented in Table 4.8 to 4.14.

4.4.1.1 Larval weight

Nitrogen level

Silkworms fed with mulberry leaves raised by applying different levels of N through CAN had significantly influenced the larval weight of second, third, fourth and fifth instars but it was non-significant for first instar. Highest larval weight was noticed with 125 kg/ha/yr (0.2845, 1.537, 7.582 and 43.07 g/10 larvae) over 100 (0.2744, 1.446, 7.075 and 40.07 g) and 75 kg/ha/yr (0.2663, 1.354, 6.500 and 36.42 g) with statistical variations among them during second, third, fourth and fifth instars, respectively.

Feeding method

The larvae of second, third, fourth and fifth instars fed through different methods had marked influence on larval weight with highest being on whole shoots (0.2772, 1.469, 7.183 and 40.67 g), followed by chopped shoots (0.2751, 1.446, 7.084 and 39.76 g) and whole leaves (0.2730, 1.423, 6.890 and 39.13 g) for respective instars. However, feeding method had no impact on weight of first instar larvae (Table 4.8 and 4.9).

Feeding frequency

Number of feeds provided per day caused significant variation with regard to larval weight. A regime of 5 feeds/day recorded highest larval weight of 0.2769, 1.465, 7.202 and 40.57 g during second, third, fourth and fifth instars, followed by 4 feeds/day (0.2760, 1.454, 7.120 and 40.13 g) and 3 feeds/day (0.2724, 1.418, 6.835 and 38.86 g). Feeding schedule however had no influence on first instar larval weight.

Nitrogen level x Feeding method

Silkworms provided with mulberry whole shoots raised by applying N @ 125 kg/ha/yr recorded significantly highest larval weight (0.2870, 1.563, 7.638 and 43.49 g), followed by chopped shoots (0.2844, 1.534, 7.585 and 43.18 g) and whole leaves (0.2822, 1.513, 7.523, and 42.55 g) at the same level of N during second, third, fourth and fifth instars, respectively. However, the combinations 100 kg N/ha/yr with whole shoots, chopped shoots and whole leaves ; 75 kg N/ha/yr with whole shoots and chopped shoots performed next best for larval weight and the weight was lowest with 75 kg/ha/yr x whole leaves (0.2649, 1.334, 6.289 and 35.61 g).

Nitrogen level x Feeding frequency

The combination of N level and frequency of feeding profoundly influenced the larval weight. Significantly highest larval weight resulted with the combination of N @ 125 kg/ha/yr x 5 feeds/day (0.2868, 1.561, 7.633 and 43.83 g), closely followed by 4 feeds/day (0.2852, 1.541, 7.629 and 43.11 g) and 3 feeds/day (0.2815, 1.509, 7.485 and 42.28 g) at the same level of N for second, third, fourth and fifth instars, respectively. The combinations 100 kg N/ha/yr x 5, 4 and 3 feeds/day and 75 kg/ha/yr x 5 and 4 feeds/day were next best with respect to larval weight and the least larval weight was noticed in 75 kg N/ha/yr x 3 feeds/day (0.2640, 1.327, 6.111 and 35.49 g) (Table 4.8 and 4.9).

Feeding method x Feeding frequency

The treatment combinations of whole shoots x 4 feeds/day and whole shoots x 5 feeds/day recorded significantly higher larval weight during second (0.2789 and 0.2788 g), third (1.488 and 1.486 g), fourth (7.334 and 7.333 g) and fifth instars (41.14 and 41.26 g) with no tangible difference among them. Next in the order were the combinations of chopped shoots x 5 and 4 feeds/day ; whole leaves x 5 feeds/day ; whole shoots x 3 feeds/day ; chopped shoots x 3 feeds/day and whole leaves x 4 feeds/day that performed better over whole leaves x 3 feeds/day (0.2712, 1.407, 6.705 and 38.33 g) and it yielded the least weight.

Nitrogen level x Feeding method x Feeding frequency

Silkworms fed with mulberry raised through varied levels of N, different methods and frequencies of feeding had marked influence on larval weight. The combination of N @ 125 kg/ha/yr x whole shoots x 5 feeds/day recorded highest larval weight in second (0.2895 g), third (1.596 g), fourth (7.797 g) and fifth instar (44.83 g) and was found on par with 125 kg N/ha/hr x whole shoots x 4 feeds/day (0.2883, 1.575, 7.688 and 43.81 g) and the weight was least with 75 kg N/ha/yr x whole leaves x 3 feeds/day (0.2630, 1.312, 6.015 and 34.85 g) (Table 4.8 ; 4.9 and Fig. 4.1).

Table 4.8 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on young-age larval weight (g/ 10 larvae)

nstar	N		M		F		N x M				N x F				M x F				N x M x F									
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
	N_1	0.0544	M_1	0.0551	F_1	0.0551	N_1	0.0542	0.0546	0.0545	N_1	0.0542	0.0544	0.0547	M_1	0.0549	0.0550	0.0553	M_1	0.0540	0.0542	0.0545	0.0550	0.0550	0.0551	0.0558	0.0560	0.0564
	N_2	0.0552	M_2	0.0557	F_2	0.0554	N_2	0.0550	0.0554	0.0553	N_2	0.0550	0.0553	0.0554	M_2	0.0552	0.0557	0.0559	M_2	0.0544	0.0548	0.0548	0.0551	0.0555	0.0556	0.0562	0.0572	0.0574
	N_3	0.0565	M_3	0.0554	F_3	0.0556	N_3	0.0561	0.0569	0.0564	N_3	0.0560	0.0566	0.0569	M_3	0.0550	0.0555	0.0556	M_3	0.0541	0.0546	0.0547	0.0550	0.0554	0.0554	0.0560	0.0565	0.0568
S.Em ±		0.011		0.011		0.011			0.019				0.019				0.019							0.060				
CD.at 5%		-		-		-			-				-				-							-				
	N_1	0.2663	M_1	0.2730	F_1	0.2724	N_1	0.2649	0.2679	0.2662	N_1	0.2640	0.2672	0.2678	M_1	0.2712	0.2731	0.2748	M_1	0.2630	0.2650	0.2667	0.2703	0.2723	0.2735	0.2802	0.2820	0.2842
I	N_2	0.2744	M_2	0.2772	F2	0.2760	N_2	0.2720	0.2767	0.2746	N_2	0.2716	0.2755	0.2762	M_2	0.2739	0.2789	0.2788	M_2	0.2655	0.2693	0.2688	0.2730	0.2790	0.2781	0.2831	0.2883	0.2895
	N_3	0.2845	M_3	0.2751	F_3	0.2769	N_3	0.2822	0.2870	0.2844	N_3	0.2815	0.2852	0.2868	M_3	0.2721	0.2759	0.2772	M_3	0.2636	0.2673	0.2678	0.2715	0.2751	0.2771	0.2811	0.2854	0.2866
S.Em ±		0.001		0.001		0.001			0.001				0.001				0.001							0.010				
CD.at 5%		0.002		0.002		0.002			0.003				0.003				0.003							0.030				
	N_1	1.354	M_1	1.423	F_1	1.418	N_1	1.334	1.374	1.354	N_1	1.327	1.336	1.368	M_1	1.407	1.419	1.441	M_1	1.312	1.340	1.351	1.409	1.409	1.443	1.502	1.510	1.529
II	N_2	1.446	M_2	1.469	F_2	1.454	N_2	1.420	1.468	1.449	N_2	1.419	1.454	1.464	M_2	1.432	1.488	1.486	M_2	1.349	1.393	1.381	1.430	1.496	1.480	1.518	1.575	1.596
	N_3	1.537	M_3	1.446	F_3	1.465	N_3	1.513	1.563	1.534	N_3	1.509	1.541	1.561	M_3	1.416	1.453	1.468	M_3	1.321	1.366	1.374	1.419	1.457	1.471	1.507	1.537	1.559
S.Em ±		0.015		0.015		0.015			0.026				0.026				0.026							0.080				
CD.at 5%		0.042		0.042		0.042			0.073				0.073				0.073							0.130				

N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

Table 4.9 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on late-age larval weight (g/ 10 larvae)

Instar		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
	N_1	6.500	M_1	6.890	F_1	6.835	N_1	6.289	6.726	6.483	N_1	6.111	6.187	6.700	M_1	6.705	6.891	7.074	M_1	6.015	6.284	6.569	6.670	6.748	7.155	7.429	7.642	7.498
IV	N_2	7.075	M_2	7.183	F_2	7.120	N_2	6.858	7.185	7.183	N_2	6.834	7.120	7.272	M_2	6.882	7.334	7.333	M_2	6.439	6.914	6.825	6.777	7.402	7.376	7.430	7.686	7.797
	N_3	7.582	M_3	7.084	F_3	7.202	N_3	7.523	7.638	7.585	N_3	7.485	7.629	7.633	M_3	6.920	7.134	7.198	M_3	6.108	6.636	6.705	7.055	7.208	7.285	7.595	7.558	7.603
S.Em ±		0.040		0.040		0.040			0.069				0.069				0.069							0.210				
C.D.at 5%		0.113		0.113		0.113			0.196				0.196				0.196							0.340				
	N_1	36.42	M_1	39.13	F_1	38.86	N_1	35.61	37.32	36.31	N_1	35.49	36.74	37.02	M_1	38.33	39.13	39.92	M_1	34.85	35.72	36.27	38.33	39.10	40.25	41.83	42.58	43.24
V	N_2	40.07	M_2	40.67	F2	40.13	N_2	39.23	41.20	39.77	N_2	38.82	40.52	40.86	M_2	39.61	41.14	41.26	M_2	36.49	37.84	37.64	39.50	42.4	41.71	42.86	43.81	44.83
	N_3	43.07	M_3	39.76	F_3	40.57	N_3	42.55	43.49	43.18	N_3	42.28	43.11	43.83	M_3	38.64	40.10	40.53	M_3	35.13	36.66	37.15	38.63	40.06	40.63	42.15	43.58	43.80
S.Em ±		0.194		0.194		0.194			0.336				0.336				0.336							1.000				
C.D. at 5%		0.550		0.550		0.550			0.953				0.953				0.953							1.650				

N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

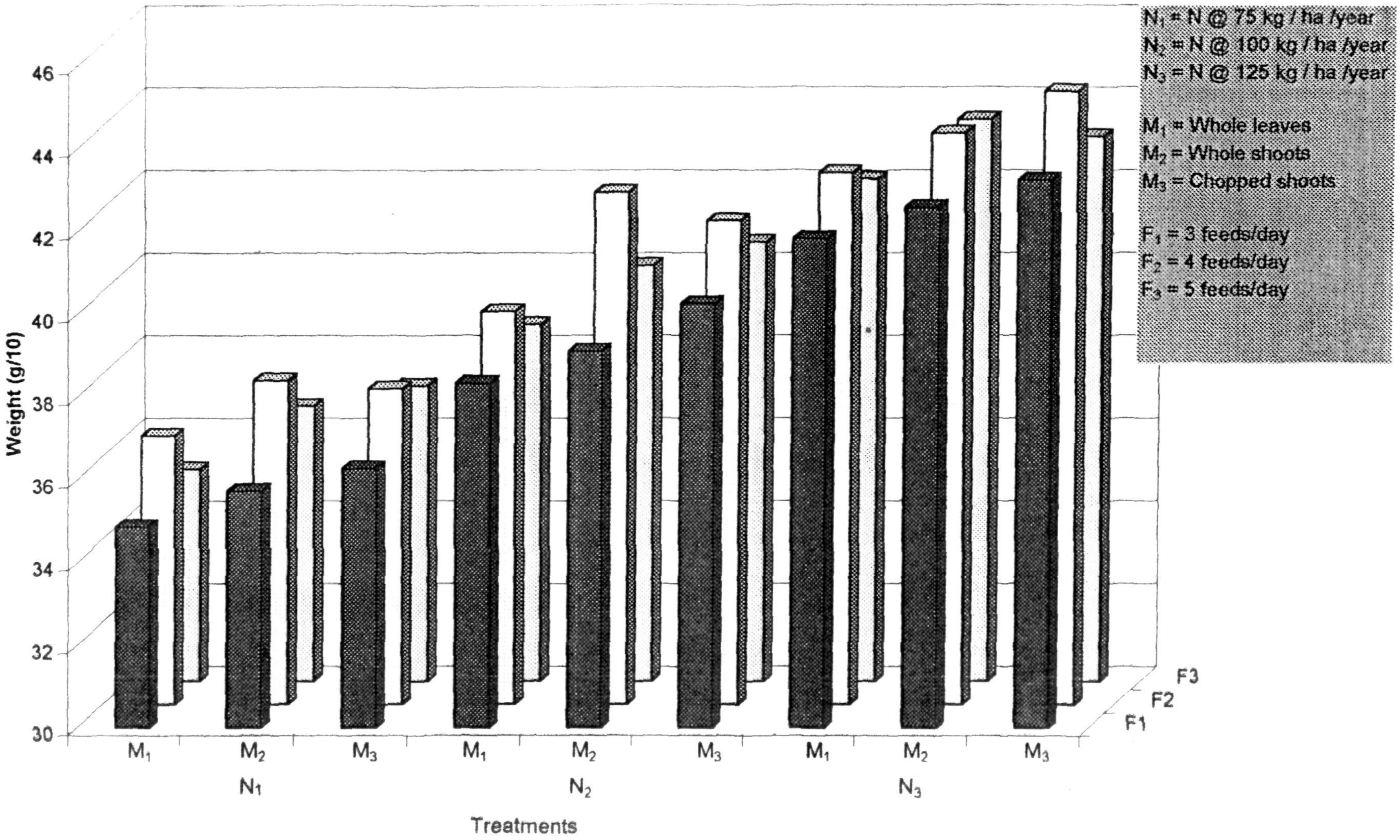


Fig. 4.1 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on mature larval weight

4.4.1.2 Larval duration

Nitrogen level

Silkworms fed with mulberry leaves raised under varied N levels did influence the larval duration. Significantly shorter duration was encountered at 125 kg N/ha/yr during first (4.000 days), second (3.000 days), third (4.173 days), fourth (5.716 days) and fifth instars (8.440 days) and total duration (25.55 days) as compared to that at 100 (4.200, 3.160, 4.260, 6.300, 8.773 and 26.69 days) and 75 kg N/ha/yr (4.500, 3.330, 4.523, 6.663, 9.387 and 28.40 days).

Feeding method

Feeding methods exerted seldom significant effect on larval duration during young-age, but the effects were significant with late-age rearing and total duration. Significantly shorter larval duration was noticed with chopped shoots (6.079 days) during fourth instar, while fifth instar and total duration was shorter with whole shoots (8.738 and 26.61 days). However, worms fed on whole leaves recorded longer fourth (6.400 days) and fifth instar (8.996 days) and total larval duration (27.16 days) (Table 4.10 and 4.11).

Feeding frequency

Rearing of silkworms with different feeding regimes caused marked influence on late-age larval duration and total larval duration, but the effect was non-significant with young-age worms. Silkworms provided 5 feeds/day recorded shortest duration of fourth (6.089 days) and fifth instar (8.738 days) and total larval duration (26.61 days) compared to 4 feeds/day (6.188, 8.867 and 26.88 days) and 3 feeds/day (6.402, 8.995 and 27.16 days).

Nitrogen level x Feeding method

Silkworms which received mulberry raised using different N levels through different methods exhibited marked influence on larval duration. Silkworms supplied with whole leaves, whole shoots and chopped shoots raised at 125, 100 and 75 kg N/ha/yr registered larval duration of 4.000, 4.200 and 4.500 days ; 3.000, 3.160 and 3.330 days during first and second instars, respectively. Further, the trend was similar for third, fourth and fifth instars and total larval duration with shortest being in the combinations of 125, 100 and 75 kg N/ha/yr x whole shoots, chopped shoots and whole leaves and the latter combination recorded longer larval duration.

Nitrogen level x Feeding frequency

The interaction of N level and feeding regime had marked effect on larval duration both with young and late-age larvae. The combinations of 125, 100 and 75 Kg N/ha/hr x 3, 4 and 5 feeds/day recorded larval duration of 4.000, 4.200 and 4.500 days and 3.000, 3.160 and 3.330 days during first and second instars, respectively. Further, the pattern was similar for third, fourth and fifth instars and total larval duration, the shortest being in the combination of 125 kg N/ha/yr x 5 feeds/day (4.160, 5.497, 8.330 and 25.32 days). Larval duration was longer with 75 kg N/ha/yr x whole leaves (Table 4.10 and 4.11).

Feeding method x Feeding frequency

Silkworms reared through different methods and feeding regimes had no influence on the duration of young-age larvae compared to late-age larvae. Fourth instar larvae exhibited shorter duration of 6.163 days with whole shoots x 5 and 4 feeds/day

Table 4.10 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on young-age larval duration (days)

Instar		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
	N_1	4.500	M_1	4.233	F_1	4.233	N_1	4.500	4.500	4.500	N_1	4.500	4.500	4.500	M_1	4.233	4.233	4.233	M_1	4.500	4.500	4.500	4.200	4.200	4.200	4.000	4.000	4.000
I	N_2	4.200	M_2	4.233	F_2	4.233	N_2	4.200	4.200	4.200	N_2	4.200	4.200	4.200	M_2	4.233	4.233	4.233	M_2	4.500	4.500	4.500	4.200	4.200	4.200	4.000	4.000	4.000
	N_3	4.000	M_3	4.233	F_3	4.233	N_3	4.000	4.000	4.000	N_3	4.000	4.000	4.000	M_3	4.233	4.233	4.233	M_3	4.500	4.500	4.500	4.200	4.200	4.200	4.000	4.000	4.000
S.Em ±		0.038		0.038		0.038			0.067				0.067				0.067							0.200				
C.D. at 5%		0.109		-		-			0.189				0.189				-							0.330				
	N_1	3.330	M_1	3.163	F_1	3.163	N_1	3.330	3.330	3.330	N_1	3.330	3.330	3.330	M_1	3.163	3.163	3.163	M_1	3.330	3.330	3.330	3.160	3.160	3.160	3.000	3.000	3.000
II	N_2	3.160	M_2	3.163	F2	3.163	N_2	3.160	3.160	3.160	N_2	3.160	3.160	3.160	M_2	3.163	3.163	3.163	M_2	3.330	3.330	3.330	3.160	3.160	3.160	3.000	3.000	3.000
	N_3	3.000	M_3	3.163	F_3	3.163	N_3	3.000	3.000	3.000	N_3	3.000	3.000	3.000	M_3	3.163	3.163	3.163	M_3	3.330	3.330	3.330	3.160	3.160	3.160	3.000	3.000	3.000
S.Em ±		0.038		0.038		0.038			0.067				0.067				0.067							0.200				
C.D. at 5%		0.109		-		-			0.189				0.189				-							0.300				
	N_1	4.523	M_1	4.366	F_1	4.366	N_1	4.607	4.440	4.523	N_1	4.607	4.523	4.440	M_1	4.397	4.397	4.303	M_1	4.660	4.660	4.500	4.330	4.330	4.250	4.200	4.200	4.160
III	N_2	4.260	M_2	4.272	F_2	4.319	N_2	4.303	4.217	4.260	N_2	4.303	4.260	4.217	M_2	4.303	4.257	4.257	M_2	4.500	4.410	4.410	4.250	4.200	4.200	4.160	4.160	4.160
	N_3	4.173	M_3	4.319	F_3	4.272	N_3	4.187	4.160	4.173	N_3	4.187	4.173	4.160	M_3	4.397	4.303	4.257	M_3	4.660	4.500	4.410	4.330	4.250	4.200	4.200	4.160	4.160
S.Em ±		0.035		0.035		0.035			0.061				0.061				0.061							0.180				
C.D. at 5%		0.100		-		-			0.173				0.173				-							0.300				

N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

Table 4.11 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on late-age and total larval duration (days)

Instar		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
IV	N_1	6.663	M_1	6.400	F_1	6.402	N_1	6.773	6.553	6.663	N_1	6.773	6.663	6.553	M_1	6.467	6.460	6.273	M_1	6.830	6.830	6.660	6.410	6.410	6.330	6.160	6.140	5.830
	N_2	6.300	M_2	6.200	F_2	6.188	N_2	6.383	6.217	6.300	N_2	6.383	6.300	6.216	M_2	6.273	6.163	6.163	M_2	6.660	6.500	6.500	6.330	6.160	6.160	5.830	5.830	5.830
	N_3	5.716	M_3	6.079	F_3	6.089	N_3	6.043	5.830	5.273	N_3	6.050	5.600	5.497	M_3	6.467	5.940	5.830	M_3	6.830	6.660	6.500	6.410	6.330	6.160	6.160	5.830	5.830
S.Em ±		0.090		0.090		0.090			0.156				0.156				0.156							0.470				
C.D. at 5%		0.255		0.255		0.255			0.442				0.442				0.442							0.760				
V	N_1	9.387	M_1	8.996	F_1	8.995	N_1	9.607	9.167	9.387	N_1	9.607	9.387	9.167	M_1	9.050	9.050	8.887	M_1	9.660	9.660	9.500	8.830	8.830	8.830	8.660	8.660	8.330
	N_2	8.773	M_2	8.738	F2	8.867	N_2	8.830	8.717	8.773	N_2	8.830	8.773	8.717	M_2	8.887	8.663	8.663	M_2	9.500	9.000	9.000	8.830	8.660	8.660	8.330	8.330	8.330
	N_3	8.440	M_3	8.867	F_3	8.738	N_3	8.550	8.330	8.440	N_3	8.550	8.440	8.330	M_3	9.050	8.887	8.663	M_3	9.660	9.500	9.000	8.830	8.830	8.660	8.660	8.330	8.330
S.Em ±		0.038		0.038		0.038			0.067				0.067				0.067							0.200				
C.D. at 5%		0.109		0.109		0.109			0.189				0.189				0.189							0.330				
Total Duration	N_1	28.40	M_1	27.16	F_1	27.16	N_1	28.82	27.99	28.40	N_1	28.82	28.40	27.99	M_1	27.31	27.31	26.86	M_1	28.98	28.98	28.49	26.93	26.93	26.77	26.02	26.02	25.32
	N_2	26.69	M_2	26.61	F_2	26.88	N_2	26.88	26.51	26.69	N_2	26.88	26.69	26.51	M_2	26.86	26.48	26.48	M_2	28.49	27.74	27.74	26.77	26.38	26.38	25.32	25.32	25.32
	N_3	25.55	M_3	26.88	F_3	26.61	N_3	25.79	25.32	25.55	N_3	25.79	25.55	25.32	M_3	27.31	26.86	26.48	M_3	28.98	28.49	27.74	26.93	26.77	26.38	26.02	25.32	25.32
S.Em ±		0.038		0.038		0.038			0.066				0.066				0.066							0.200				
C.D. at 5%		0.109		0.109		0.109			0.188				0.188				0.188							0.300				

N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

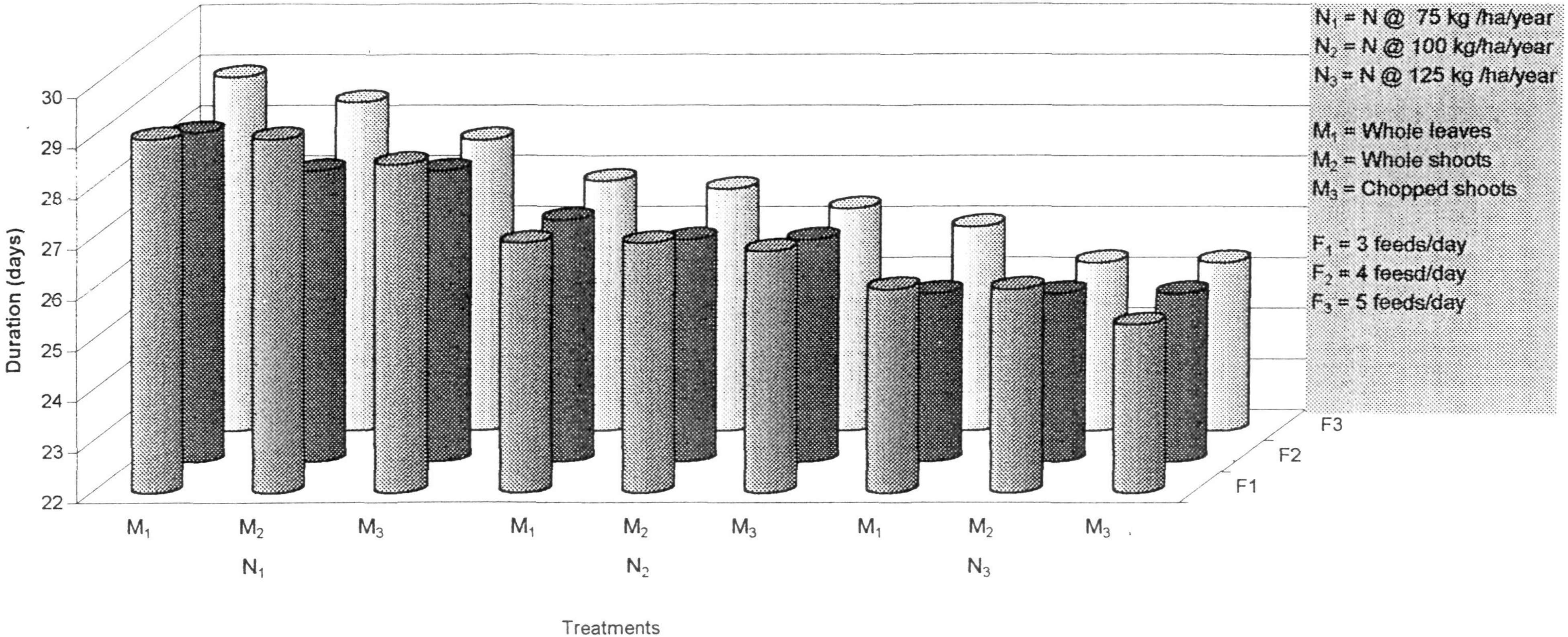


Fig. 4. 2 : Infuence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on total larval duration

combinations, while fifth instar and total larval duration was shorter with whole shoots x 5 and 4 feeds/day and chopped shoots x 5 feeds/day (8.663 and 26.48 days). Whole leaves x 3 feeds/day (6.467, 9.050 and 27.31 days) and whole leaves x 4 feeds/day (6.460, 9.050 and 27.31 days) witnessed longer duration during fourth and fifth instars and total larval duration.

Nitrogen level x Feeding method x Feeding frequency

The combination of N level, method and frequency of feeding caused significant variation in respect of larval duration. During first and second instars, the duration was shorter (125 kg N/ha/yr) irrespective of method and frequency of feeding which recorded 4.000 and 3.000 days, respectively. However, the combinations 125 kg N/ha/yr with whole shoots x 5, 4 and 3 feeds/day ; chopped shoots x 5 and 4 feeds/day and whole leaves x 5 feeds/day yielded shorter duration during third (4.160 days), fourth (5.830 days) and fifth instars (8.330 days) and total larval duration (25.32 days). Similarly, the duration was longer with 75 kg N/ha/yr (4.500 and 3.330 days) irrespective of method and frequency of feeding during first and second instars and it was longer for 75 kg N/ha/yr with chopped shoots x 3 feeds/day ; whole leaves x 4 and 3 feeds/day during third (4.660 days), fourth (6.830 days) and fifth instar (9.660 days) and total larval duration (28.98 days) (Table 4.10 ; 4.11 and Fig.4.2).

4.4.1.3 Larval survival

Nitrogen level

Differences were significant with regard to larval survival as influenced by N levels. Highest survival was found with 125 kg/ha/yr (99.00, 98.33, 96.50, 95.06 and 91.33%), followed by 100 (98.50, 97.67, 95.50, 93.48 and 87.43%) and 75 kg/ha/yr (98.00, 96.37, 94.33, 90.94 and 82.94%) during first, second, third, fourth and fifth instars, respectively with clear cut differences among them.

Feeding method

Silkworms supplied with mulberry through different methods had significant influence on survival during second, third, fourth and fifth instars, while that of first instar was non-significant. Worms that received mulberry through whole shoots registered higher survival of larvae during second (97.61%), third (95.72%) fourth (93.65%) and fifth instars (88.11%) along with that on chopped shoots (97.48, 95.44, 93.17 and 87.43%). It was lowest with whole leaves (97.28, 97.17, 92.67 and 86.17%) (Table 4.12 and 4.13).

Feeding frequency

Feeding regimes of silkworms exhibited marked influence on survival of larvae only during second, third, fourth and fifth instars. Survival was significantly higher with regime of 5 feeds/day (97.61, 95.72, 93.70 and 88.31%) and 4 feeds/day (97.44, 95.44, 93.22 and 87.39%). However, the worms fed 3 times a day registered the least survival (97.31, 95.17, 92.56 and 86.00%).

Nitrogen level x Feeding method

The survival did get influenced by the combination of N level and feeding method. Highest larval survival was noticed when worms were fed with whole shoots raised at 125 kg N/ha/yr (98.50, 96.83, 95.50 and 92.17%), chopped shoots (98.33, 96.50, 95.00 and 91.50%) and whole leaves (98.17, 96.17, 94.67 and 90.30%). The treatment combination 100 kg N/ha/yr x whole shoots, chopped shoots and whole leaves ; 75 kg N/ha/yr x whole shoots and chopped shoots were found next best for survival. However, it was least with 75 kg N/ha/yr x whole leaves (96.17, 94.17, 90.17 and 82.00%) (Table 4.12 and 4.13).

Nitrogen level x Feeding frequency

The combination of N level and frequency of feeding significantly influenced the larval survival. Silkworms fed 5, 4 and 3 times a day with mulberry raised at 125 kg N/ha/yr recorded highest survival during second (98.50, 98.33 and 98.17%), third (96.83, 96.50 and 96.17%), fourth (95.50, 95.00 and 94.67%) and fifth instar (92.33, 91.50 and 90.17%). Further, the combinations viz., 100 and 75 kg N/ha/yr with 5, 4 and 3 feeds/day were next superior with the latter combination being the least in respect of survival (96.28, 94.17, 89.83 and 81.83%).

Feeding method x Feeding frequency

Silkworms supplied with mulberry through different methods at varied schedules exerted significant influence on larval survival during late-age worms, but did not influence it during young-age. The interaction of whole shoots x 5 and 4 feeds/day and chopped shoots x 5 feeds/day recorded higher survival of larvae during fourth (93.94, 93.83 and 93.83%) and fifth instar (89.00, 88.50 and 88.94%) and chopped shoots x 4 feeds/day, whole leaves x 5 feeds/day, whole shoots x 3 feeds/day, whole leaves x 4 feeds/day and chopped shoots x 3 feeds/day were the next in order. However, the combination of whole leaves x 3 feeds/day stood least for survival (92.17 and 85.33%).

Table 4.12 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on young-age larval survival (%)

Instar		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
	N_1	98.00 (82.05)	M_1	98.50 (83.16)	F_1	98.50 (83.16)	N_1	98.00 (82.05)	98.00 (82.05)	98.00 (82.05)	N_1	98.00 (82.05)	98.00 (82.05)	98.00 (82.05)	M_1	98.50 (83.16)	98.50 (83.16)	98.50 (83.16)	M_1	98.00 (82.05)	98.00 (82.05)	98.00 (82.05)	98.50 (83.03)	98.50 (83.03)	98.50 (83.03)	99.00 (84.39)	99.00 (84.39)	99.00 (84.39)
I	N_2	98.50 (83.03)	M_2	98.50 (83.16)	F_2	98.50 (83.16)	N_2	98.50 (83.03)	98.50 (83.03)	98.50 (83.03)	N_2	98.50 (83.03)	98.50 (83.03)	98.50 (83.03)	M_2	98.50 (83.16)	98.50 (83.16)	98.50 (83.16)	M_2	98.00 (82.05)	98.00 (82.05)	98.00 (82.05)	98.50 (83.03)	98.50 (83.03)	98.50 (83.03)	99.00 (84.39)	99.00 (84.39)	99.00 (84.39)
	N_3	99.00 (84.39)	M_3	98.50 (83.16)	F_3	98.50 (83.16)	N_3	99.00 (84.39)	99.00 (84.39)	99.00 (84.39)	N_3	99.00 (84.39)	99.00 (84.39)	90.00 (84.39)	M_3	98.50 (83.16)	98.50 (83.16)	98.50 (83.16)	M_3	98.00 (82.05)	98.00 (82.05)	98.00 (82.05)	98.50 (83.03)	98.50 (83.03)	98.50 (83.03)	99.00 (84.39)	99.00 (84.39)	99.00 (84.39)
S.Em ±		0.318		0.318		0.318			0.550				0.550				0.550							1.650				
C.D. at 5%		0.901		-		-			-				-				-							-				
	N_1	96.37 (79.05)	M_1	97.28 (80.66)	F_1	97.31 (80.71)	N_1	96.17 (78.76)	96.50 (79.24)	96.44 (79.15)	N_1	96.28 (78.91)	96.33 (79.00)	96.50 (79.24)	M_1	97.17 (80.46)	97.17 (80.46)	97.50 (81.07)	M_1	96.00 (78.52)	96.00 (78.52)	96.50 (79.24)	97.50 (80.93)	97.50 (80.93)	97.50 (80.93)	98.00 (81.91)	98.00 (81.91)	98.50 (83.03)
II	N_2	97.67 (81.26)	M_2	97.61 (81.28)	F2	97.44 (80.97)	N_2	97.50 (80.93)	97.83 (81.59)	97.67 (81.26)	N_2	97.50 (80.93)	97.67 (81.26)	97.83 (81.59)	M_2	97.50 (81.07)	97.67 (81.39)	97.67 (81.39)	M_2	96.50 (79.24)	96.50 (79.24)	96.50 (79.24)	97.50 (80.93)	98.00 (81.91)	98.00 (81.91)	98.50 (83.03)	98.50 (83.03)	98.50 (83.03)
	N_3	98.33 (82.66)	M_3	97.48 (81.02)	F_3	97.61 (81.28)	N_3	98.17 (82.29)	98.50 (83.03)	98.33 (82.66)	N_3	98.17 (82.29)	98.33 (82.66)	98.50 (83.03)	M_3	97.28 (80.61)	97.50 (81.07)	97.67 (81.39)	M_3	96.33 (78.98)	96.50 (79.24)	96.50 (79.24)	97.50 (80.93)	97.50 (80.93)	98.00 (81.91)	98.00 (81.91)	98.50 (83.03)	98.50 (83.03)
S.Em ±		0.199		0.199		0.199			0.344				0.344				0.344							1.030				
C.D. at 5%		0.564		0.564		0.564			0.976				0.976				-							1.690				
	N_1	94.33 (76.27)	M_1	95.17 (77.40)	F_1	95.17 (77.40)	N_1	94.17 (76.06)	94.50 (76.47)	94.33 (76.27)	N_1	94.17 (76.06)	94.33 (76.27)	94.50 (76.47)	M_1	95.00 (77.17)	95.00 (77.17)	95.50 (77.86)	M_1	94.00 (75.85)	94.00 (75.85)	94.50 (76.47)	95.00 (77.12)	95.00 (77.12)	95.50 (77.80)	96.00 (78.52)	96.00 (78.52)	96.50 (79.29)
III	N_2	95.50 (77.82)	M_2	95.72 (78.20)	F_2	95.44 (77.80)	N_2	95.17 (77.35)	95.83 (78.28)	95.50 (77.82)	N_2	95.17 (77.35)	95.50 (77.82)	95.83 (78.28)	M_2	95.50 (77.86)	95.83 (78.37)	95.83 (78.37)	M_2	94.50 (76.47)	94.50 (76.47)	94.50 (76.47)	95.50 (77.80)	96.00 (78.52)	96.00 (78.52)	96.50 (79.29)	97.00 (80.12)	97.00 (80.12)
	N_3	96.50 (79.31)	M_3	95.44 (77.80)	F_3	95.72 (78.20)	N_3	96.17 (78.78)	96.83 (79.84)	96.50 (79.31)	N_3	96.17 (78.78)	96.50 (79.31)	96.83 (79.84)	M_3	95.00 (77.17)	95.50 (77.86)	95.83 (78.37)	M_3	94.00 (75.85)	94.50 (76.47)	94.50 (76.47)	95.00 (77.12)	95.50 (77.80)	96.00 (78.52)	96.00 (78.52)	96.50 (79.29)	97.00 (80.12)
S.Em ±		0.273		0.273		0.273			0.472				0.472				0.472							1.420				
C.D. at 5%		0.773		0.773		0.773			1.339				1.339				-							2.320				

Figures in the parentheses are angular transformed values

N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

Table 4.13 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on late-age larval survival (%)

Instar		N		M		F		N x M				N x F				M x F				N x M x F								
																				N₁			N₂			N₃		
								M₁	M₂	M₃		F₁	F₂	F₃		F₁	F₂	F₃		F₁	F₂	F₃	F₁	F₂	F₃	F₁	F₂	F₃
IV	N₁	90.94 (72.54)	M₁	92.67 (74.45)	F₁	92.56 (74.35)	N₁	90.17 (71.79)	91.67 (73.25)	91.00 (72.58)	N₁	89.83 (71.45)	91.17 (72.76)	91.83 (73.41)	M₁	92.17 (73.96)	92.50 (74.25)	93.33 (75.14)	M₁	89.00 (70.68)	90.00 (71.62)	91.50 (73.05)	93.00 (74.68)	93.00 (74.66)	93.50 (75.26)	94.50 (76.52)	94.50 (76.47)	95.00 (77.12)
	N₂	93.48 (75.24)	M₂	93.65 (75.55)	F₂	93.22 (75.05)	N₂	93.17 (74.87)	93.78 (75.58)	93.50 (75.26)	N₂	93.17 (74.87)	93.50 (75.26)	93.78 (75.58)	M₂	93.17 (74.97)	93.83 (75.75)	93.94 (75.92)	M₂	91.00 (72.56)	92.00 (73.59)	92.00 (73.59)	93.50 (75.24)	94.00 (75.85)	93.83 (75.64)	95.00 (77.12)	95.50 (77.80)	96.00 (78.52)
	N₃	95.06 (77.22)	M₃	93.17 (75.00)	F₃	93.70 (75.60)	N₃	94.67 (76.70)	95.50 (77.82)	95.00 (77.15)	N₃	94.67 (76.72)	95.00 (77.13)	95.50 (77.82)	M₃	92.33 (74.10)	93.33 (75.15)	93.83 (75.74)	M₃	89.50 (71.11)	91.50 (73.07)	92.00 (73.58)	93.00 (74.68)	93.50 (75.26)	94.00 (75.85)	94.50 (76.52)	95.00 (77.12)	95.50 (77.80)
S.Em ±		0.241		0.241		0.241			0.418				0.418				0.418							1.250				
CD at 5%		0.685		0.685		0.685			1.186				1.186				1.186							2.050				
V	N₁	82.94 (65.63)	M₁	86.17 (68.34)	F₁	86.00 (68.19)	N₁	82.00 (64.91)	84.17 (66.58)	82.67 (65.41)	N₁	81.83 (64.78)	83.33 (65.92)	83.67 (66.18)	M₁	85.33 (67.63)	86.17 (68.33)	87.00 (69.07)	M₁	81.00 (64.16)	82.00 (64.90)	83.00 (65.66)	85.50 (67.62)	86.50 (68.46)	86.50 (68.46)	89.50 (71.12)	90.00 (71.62)	91.50 (73.09)
	N₂	87.43 (69.34)	M₂	88.11 (70.05)	F2	87.39 (69.41)	N₂	86.17 (68.18)	88.11 (69.77)	88.00 (70.06)	N₂	86.00 (68.03)	87.33 (69.18)	88.94 (70.80)	M₂	86.83 (68.89)	88.50 (70.37)	89.00 (70.89)	M₂	83.00 (65.65)	84.50 (66.83)	85.00 (67.24)	86.50 (68.46)	88.50 (70.18)	89.00 (70.68)	91.00 (72.56)	92.50 (74.11)	93.00 (74.76)
	N₃	91.33 (72.96)	M₃	87.43 (69.53)	F₃	88.31 (70.33)	N₃	90.33 (71.95)	92.17 (73.81)	91.50 (73.12)	N₃	90.17 (71.75)	91.50 (73.13)	92.33 (73.99)	M₃	85.83 (68.05)	87.50 (69.53)	88.94 (71.01)	M₃	81.50 (64.53)	83.50 (66.04)	83.00 (65.66)	86.00 (68.04)	87.00 (68.90)	91.33 (73.25)	90.00 (71.58)	92.00 (73.65)	92.50 (74.11)
S.Em ±		0.287		0.287		0.287			0.497				0.497				0.497							1.490				
CD.at 5%		0.814		0.814		0.814			1.410				1.410				1.410							2.440				

Figures in the parentheses are angular transformed values

N= Nitrogen level : N_1= 75 kg/ha/year; N_2= 100 kg/ha/year; N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves; M_2 = Whole Shoots; M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day; F_2 = 4 feeds/day; F_3 = 5 feeds/day

Nitrogen level x Feeding method x Feeding frequency

Silkworms fed with mulberry raised at different levels of N through different methods and varied schedules showed statistical difference in respect of larval survival. The interaction of 125 kg N/ha/yr with whole shoots x 5 and 4 feeds/day ; chopped shoots x 5 feeds/day recorded significantly higher larval survival during second (98.50, 98.50 and 98.50%), third (97.00, 97.00 and 97.00%), fourth (96.00, 95.50 and 95.50%) and fifth instars (93.00, 92.50 and 92.50%). Further, 125, 100 and 75 kg N/ha/hr ; whole shoots, chopped shoots and whole leaves ; 5, 4 and 3 feeds/day with irrespective of schedules stood next best and the latter combination yielded least survival (Table 4.12 and 4.13).

4.4.1.4 ERR

Nitrogen level

The ERR was significantly influenced by feeding leaves raised at different N levels to silkworms. ERR was higher with 125 kg/ha/yr (88.44%). N at 100 (83.78%) and 75 kg/ha/yr (78.37%) stood next.

Feeding method

Supply of mulberry to silkworms through different methods did influence the extent of ERR. Whole shoot feeding was superior (84.91%) over chopped shoots (83.74%) and whole leaves (81.94%).

Feeding frequency

Schedule of feeding silkworms showed significant influence on ERR with highest being in 5 (84.50%) and 4 times a day (83.87%). However, it was lowest with 3 feeds/day (82.22%) (Table 4.14).

Nitrogen level x Feeding method

Rearing of silkworms on whole shoots raised at 125 kg N/ha/yr recorded highest ERR of 89.61 per cent together with chopped shoots (88.67%) at same level of N. The combination least effective was 75 kg N/ha/yr x whole leaves (76.28%).

Nitrogen level x Feeding frequency

Application of N @ 125 kg/ha/yr in combination with 5 feeds/day registered higher ERR (89.56%) along with 4 feeds/day (88.56%). The combination 125 kg N/ha/yr x 3 feeds/day ; 100 and 75 kg/ha/yr x 5, 4 and 3 feeds/day yielded next best ERR, the least being in the latter combination (Table 4.14).

Feeding method x Feeding frequency

Silkworms receiving mulberry shoots at feeding regime of 5 and 4 feeds a day produced highest ERR (85.56%), closely followed by chopped shoots x 5 feeds/day (84.78%). The combinations of chopped shoots x 4 feeds/day (84.22%), whole shoots x 3 feeds/day (83.67%), whole leaves x 5 feeds/day (83.22%), chopped shoots x 3 feeds/day (82.22%) and whole leaves x 4 feeds/day (81.83%) performed next best for ERR. However, ERR was least with whole leaves x 3 feeds/day (80.78%).

Nitrogen level x Feeding method x Feeding frequency

The second order interaction of N level, feeding method and feeding frequency did influence the ERR, with higher being in N @ 125 kg/ha/yr x whole shoots x 5 feeds/day (90.67%) together with whole shoots x 4 feeds/day (90.00%), chopped shoots x 5 feeds/day (89.67%) and chopped shoots x 4 feeds/day (88.83%) at same level of N. However, the combination N @ 75 kg/ha/yr x whole leaves x 3 feeds/day registered lowest ERR of 74.50 per cent (Table 4.14 and Fig.4.3).

4.4.1.5 Cocoon yield

Nitrogen level

The batch of silkworms fed on mulberry raised with the application of N @ 125 kg/ha/yr yielded highest quantity of cocoons (37.39 kg/box of 50 dfls) as compared to the application of N @ 100 (33.62 kg) and 75 kg/ha/yr (25.96 kg) with distinct differences among them.

Feeding method

Rearing of silkworms on whole shoots recorded higher cocoon yield of 33.37 kg, followed by chopped shoots (32.44 kg) and it was least with whole leaves (31.16 kg).

Feeding frequency

Number of feeds provided to silkworms per day did influence the cocoon yield. The yield was highest with 5 feeds/day (33.30 kg) and the frequencies 4 and 3 feeds/day stood next in order for cocoon yield with 32.66 and 31.03 kg (Table 4.14).

Nitrogen level x Feeding method

Method of feeding silkworms with mulberry raised at varied levels of N did influence the cocoon yield. The cocoon yield was highest with N @ 125 kg/ha/yr x whole shoots (38.11 kg), followed by chopped shoots (37.55 kg) and whole leaves (36.52 kg) at same level of N. The combinations N @ 100 kg/ha/yr x whole shoots (34.54 kg), chopped shoots (33.78 kg) and whole leaves (32.56 kg) recorded moderate cocoon yield. However, the least cocoon yield of 24.41 kg was recorded with 75 kg N/ha/yr x whole leaves.

Nitrogen level x Feeding frequency

The combination of N @ 125 kg/ha/yr with 5 feeds/day was superior for cocoon yield (38.19 kg), followed by 4 (37.56 kg) and 3 feeds/day (36.43 kg) at same N level. The yield was lowest with 75 kg N/ha/yr x 3 feeds/day (23.96 kg) and the cocoon yield in the remaining treatments varied between 26.52 to 34.29 kg (Table 4.14).

Feeding method x Feeding frequency

The silkworms that received mulberry through whole shoots at a frequency of 5 feeds/day recorded highest cocoon yield (34.12 kg), followed by whole shoots x 4 feeds/day (33.96 kg), chopped shoots x 5 feeds/day (33.47 kg), chopped shoots x 4 feeds/day (32.88 kg), whole leaves x 5 feeds/day (32.29 kg), whole shoots x 3 feeds/day (32.05 kg), whole leaves x 4 feeds/day (31.14 kg) and chopped shoots x 3 feeds/day (30.98 kg). However, the yield was lowest with the combination of whole leaves x 3 feeds/day (30.05 kg).

Nitrogen level x Feeding method x Feeding frequency

Silkworms reared on mulberry through different methods and frequencies with varied levels of N to mulberry had profound influence on cocoon yield. The interaction of N @ 125 kg/ha/yr x whole shoots x 5 feeds/day recorded the highest cocoon yield of 38.81 kg together with whole shoots x 4 feeds/day (38.41 kg) and chopped shoots x 5 feeds/day (38.34 kg) at same level of N. However, the lowest cocoon yield was noticed with N @ 75 kg/ha/yr x whole leaves x 3 feeds/day (22.71 kg) (Table 4.14).

4.4.1.6 Silk productivity

Nitrogen level

Silk productivity was found to be significantly higher in case of silkworms fed with mulberry raised by applying N @ 125 kg/ha/yr (5.185 cg/day) compared to the application of 100 (4.659 cg) and 75 kg/ha/yr (3.296 cg).

Feeding method

Silkworms reared on whole shoots excelled in silk productivity (4.550 cg) over those reared on chopped shoots (4.354 cg) and whole leaves (4.136 cg).

Feeding frequency

Silkworms supplied with mulberry 5 times a day were best with regard to silk productivity (4.559 cg). Feeding regimes of 4 (4.396 cg) and 3 feeds/day (4.087 cg) were next best (Table 4.14).

Nitrogen level x Feeding method

Silk productivity was significantly higher with the combination of N @ 125 kg/ha/yr x whole shoots (5.304 cg), followed by chopped shoots (5.185 cg) and whole leaves (5.069 cg) at same level of N. Further, the method of feeding was in the same sequence as above at 100 and 75 kg N/ha/yr with moderate silk productivity, the lowest being in the combination of 75 kg N/ha/yr x whole leaves (2.945 cg)

Nitrogen level x Feeding frequency

The combination of 125 kg N/ha/yr x 5 feeds/day recorded highest silk productivity of 5.301 cg, followed by 4 (5.201 cg) and 3 feeds/day (5.055 cg) at same level of N. N @ 75 kg/ha/yr x 3 feeds/day recorded lowest silk productivity (2.854 cg) (Table 4.14).

Feeding method x Feeding frequency

Significantly higher silk productivity of 4.710 cg was obtained with whole shoot feeding 5 times a day along with whole shoots x 4 feeds/day (4.664 cg) and chopped shoots x 5 feeds/day (4.617 cg). The combinations chopped shoots x 4 feeds/day (4.419 cg), whole leaves x 5 feeds/day (4.356 cg), whole shoots x 3 feeds/day (4.285 cg), whole leaves x 4 feeds/day (4.117 cg) and chopped shoots x 3 feeds/day (4.040 cg) were next in the order. However, whole leaves x 3 feeds/day witnessed the least silk productivity of 3.939 cg.

Nitrogen level x Feeding method x Feeding frequency

Silk productivity was markedly influenced by the method and frequency of feeding mulberry raised at different levels of N, with highest being in the combination of 125 kg N/ha/hr x whole shoots x

Table 4.14 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on ERR, cocoon yield and silk productivity

Param-eters		N		M		F	N x M				N x F				M x F				N x M x F								
																				N1			N2			N3		
								M1	M2	M3		F1	F2	F3		F1	F2	F3		F1	F2	F3	F1	F2	F3	F1	F2	F3
ERR (%)	N1	78.37 (62.32)	M1	81.94 (65.03)	F1	82.22 (65.25)	N1	76.28 (60.87)	80.11 (63.54)	78.72 (62.56)	N1	76.22 (60.84)	79.11 (62.84)	79.78 (63.29)	M1	80.78 (64.16)	81.83 (64.93)	83.22 (66.00)	M1	74.50 (59.68)	76.33 (60.89)	78.00 (62.03)	81.83 (64.78)	82.33 (65.15)	83.33 (65.92)	86.00 (68.04)	86.83 (68.74)	88.33 (70.05)
	N2	83.78 (66.28)	M2	84.91 (67.34)	F2	83.87 (66.51)	N2	82.50 (65.28)	85.00 (67.23)	83.83 (66.31)	N2	83.22 (65.84)	83.94 (66.41)	84.17 (66.58)	M2	83.67 (66.33)	85.56 (67.84)	85.56 (67.84)	M2	78.33 (62.27)	81.17 (64.30)	80.83 (64.04)	84.50 (66.83)	85.50 (67.63)	85.00 (67.23)	88.17 (69.89)	90.00 (71.58)	90.67 (72.26)
	N3	88.44 (70.18)	M3	83.74 (66.41)	F3	84.50 (67.02)	N3	87.06 (68.94)	89.61 (71.24)	88.67 (70.36)	N3	87.22 (69.08)	88.56 (70.27)	89.56 (71.20)	M3	82.22 (65.26)	84.22 (66.76)	84.78 (67.22)	M3	75.83 (60.56)	79.83 (63.32)	80.50 (63.81)	83.33 (65.91)	84.00 (66.45)	84.17 (66.58)	87.50 (69.31)	88.83 (70.50)	89.67 (71.28)
S.Em ±		0.217		0.217		0.217			0.376				0.376				0.376							1.130				
CD at 5%		0.616		0.616		0.616			1.067				1.067				1.067							1.850				
Cocoon Yield (kg/ box of 50 DFLs)	N1	25.96	M1	31.16	F1	31.03	N1	24.41	27.48	26.00	N1	23.96	26.52	27.41	M1	30.05	31.14	32.29	M1	22.71	24.39	26.14	31.80	32.56	33.31	35.65	36.48	37.43
	N2	33.62	M2	33.37	F2	32.66	N2	32.56	34.54	33.78	N2	32.68	33.90	34.29	M2	32.05	33.96	34.12	M2	25.53	28.37	28.53	33.50	35.09	35.02	37.11	38.41	38.81
	N3	37.39	M3	32.44	F3	33.30	N3	36.52	38.11	37.55	N3	36.43	37.56	38.19	M3	30.98	32.88	33.47	M3	23.65	26.80	27.55	32.75	34.05	34.53	36.53	37.79	38.34
S.Em ±		0.093		0.093		0.093			0.162				0.162				0.162							0.490				
CD at 5%		0.265		0.265		0.265			0.459				0.459				0.459							0.790				
Silk Producti-vity (cg/day)	N1	3.296	M1	4.136	F1	4.087	N1	2.945	3.653	3.308	N1	2.854	3.389	3.664	M1	3.939	4.117	4.356	M1	2.607	2.939	3.295	4.411	4.533	4.644	4.946	5.007	5.262
	N2	4.659	M2	4.550	F2	4.396	N2	4.530	4.775	4.675	N2	4.490	4.699	4.789	M2	4.285	4.664	4.710	M2	3.172	3.859	3.949	4.574	4.863	4.890	5.240	5.327	5.345
	N3	5.185	M3	4.354	F3	4.559	N3	5.069	5.304	5.185	N3	5.055	5.201	5.301	M3	4.040	4.419	4.617	M3	3.118	3.400	3.771	4.485	4.702	4.838	4.985	5.280	5.299
S.Em ±		0.034		0.034		0.034			0.053				0.053				0.053							0.170				
CD.at 5%		0.096		0.096		0.096			0.151				0.151				0.151							0.277				

Figures in the parentheses are angular transformed values

N= Nitrogen level : N_1= 75 kg/ha/year, N_2= 100 kg/ha/year, N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves, M_2 = Whole Shoots, M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day, F_2 = 4 feeds/day, F_3 = 5 feeds/day

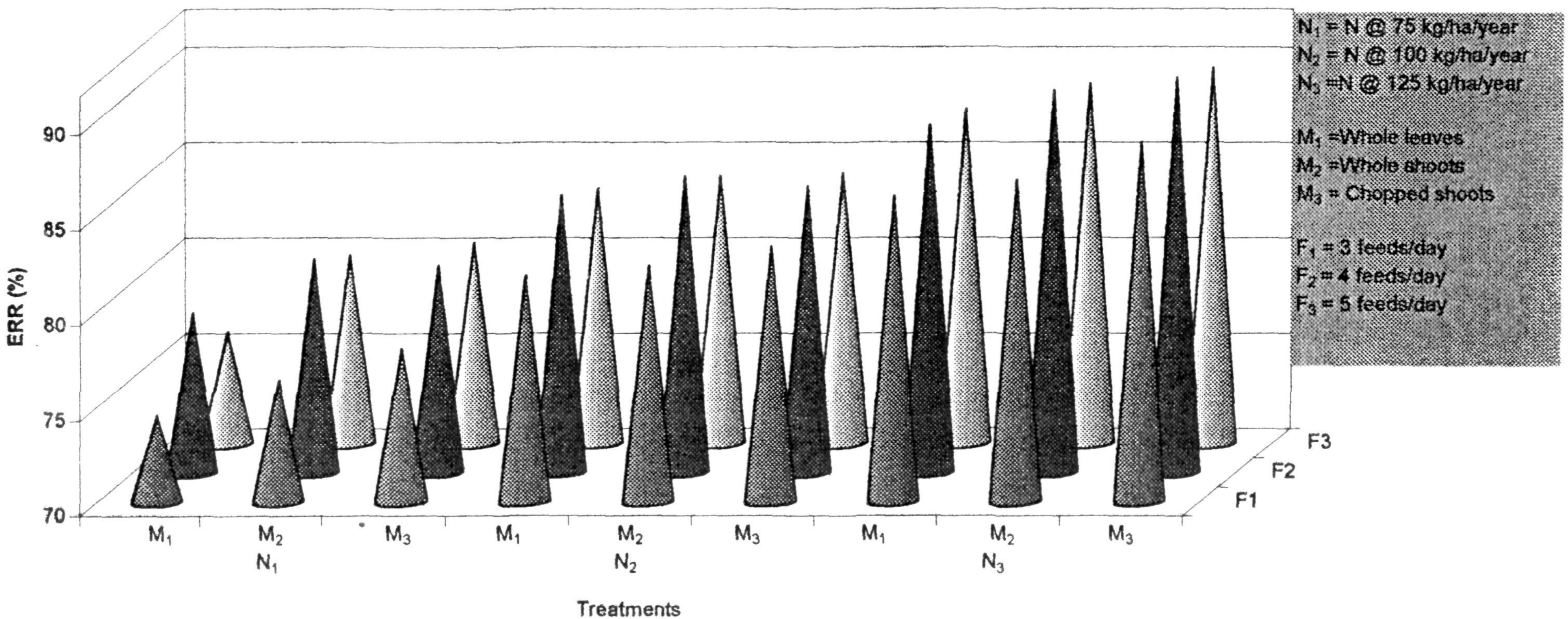


Fig. 4. 3: Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on ERR

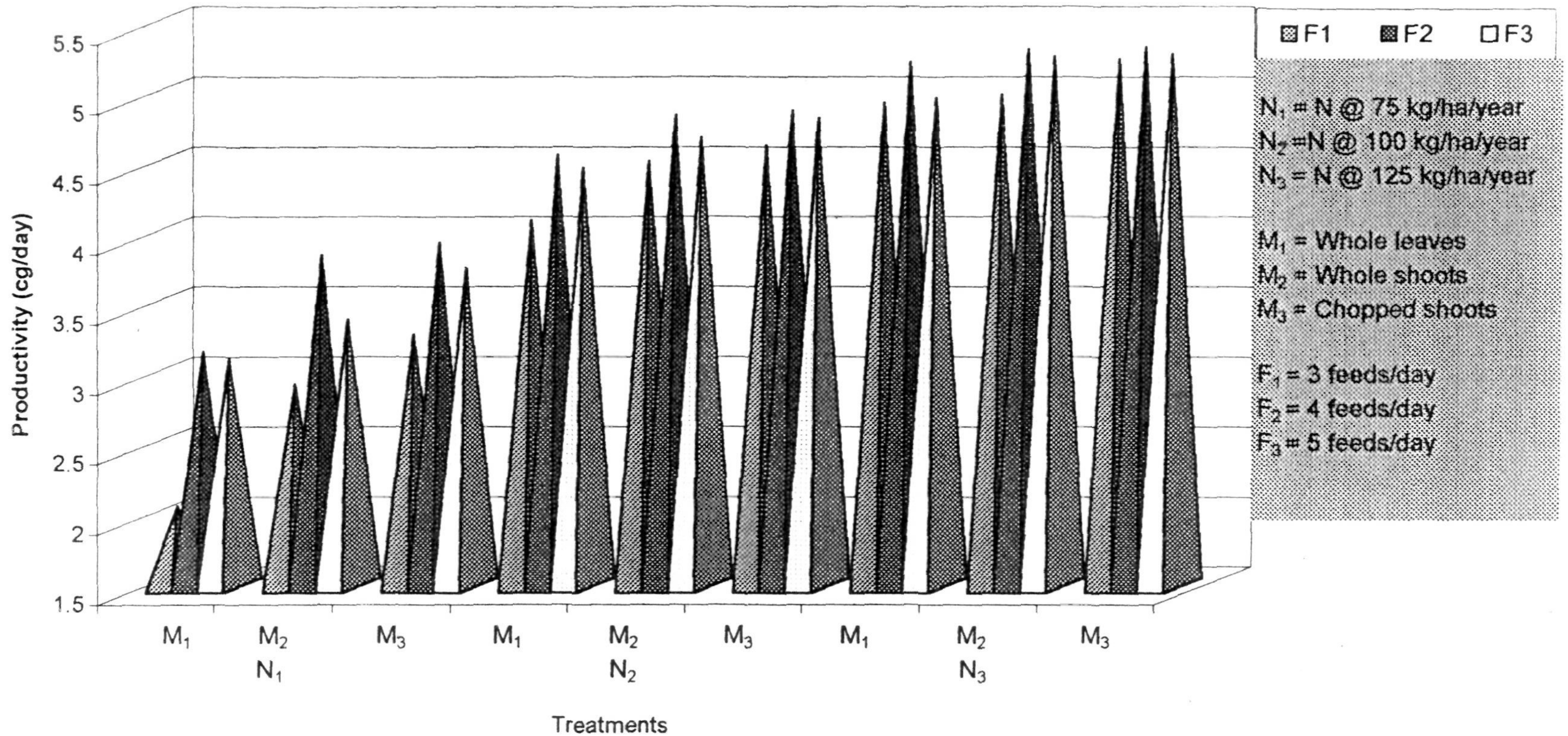


Fig.4.4 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on silk productivity

5 feeds/day (5.345 cg) together with whole shoots x 4 feeds/day (5.327 cg), chopped shoots x 5 feeds/day (5.299 cg), chopped shoots x 4 feeds/day (5.280 cg), whole leaves x 5 feeds/day (5.262 cg) and whole shoots x 3 feeds/day (5.240 cg). However, the combination of 75 kg N/ha/hr x whole leaves x 3 feeds/day registered the least silk productivity (2.607 cg) (Table 4.14 and Fig.4.4).

4.4.2 COCOON PARAMETERS

The data on the influence of method and frequency of feeding mulberry raised at varied N levels for cocoon parameters viz., cocoon weight, shell weight, shell ratio, filament length, denier, fibroin and sericin contents are presented in Table 4.15 to 4.17.

4.4.2.1 Cocoon weight

Nitrogen level

Feeding leaves of mulberry obtained from plots fertilized with N @ 125 kg/ha/yr recorded highest cocoon weight of 22.17 g/10 cocoons. N at 100 (21.38 g) and 75 kg/ha/yr (18.22 g) were next in the order.

Feeding method

The weight of cocoons was highest in the case of larvae which received mulberry through whole shoots (20.88 g) and chopped shoots (20.60 g) and it was lowest with whole leaves (20.29 g).

Feeding frequency

Silkworms supplied with mulberry at frequency of 5 times a day registered significantly higher cocoon weight of 20.89 g compared to 4 (20.69 g) and 3 feeds/day (20.19 g) with distinct differences among them (Table 4.15).

Nitrogen level x Feeding method

The interaction of N @ 125 kg/ha/yr x whole shoots recorded superior cocoon weight (22.28 g) together with chopped shoots (22.18 g) and whole leaves (22.05 g) at same level of N. The trend was similar at 100 and 75 kg N/ha/yr. However, silkworms fed with whole leaves raised at 75 kg N/ha/yr stood least of all the combinations for cocoon weight (17.67 g).

Nitrogen level x Feeding frequency

Silkworms fed 5, 4 and 3 times a day in combinations with N @ 125 kg/ha/yr recorded higher cocoon weight of 22.28, 22.21 and 22.02g. The combinations of 100 kg N/ha/yr x 5 (21.64 g), 4 (21.48 g) and 3 feeds/day (21.02 g) at same level of N performed moderately for cocoon weight. However, it was lowest with 75 kg N/ha/yr x 3 feeds/day (17.52 g) (Table 4.15).

Feeding method x Feeding frequency

Feeding of silkworms through different methods at varied frequencies influenced the cocoon weight significantly, the highest being with whole shoots x 5 feeds/day (21.14 g) along with whole shoots x 4 feeds/day (21.03 g) and chopped shoots x 5 feeds/day

(20.91 g). The cocoon weight was lowest in the combination of whole leaves x 3 feeds/day (19.96 g).

Nitrogen level x Feeding method x Feeding frequency

Silkworms that were offered mulberry through different methods and frequencies at different N levels appreciably improved the cocoon weight. Cocoon weight was higher with 125 kg N/ha/yr x whole shoots x 5 feeds/day (22.37 g) together with whole shoots x 4 feeds/day (22.32 g), chopped shoots x 5 feeds/day (22.29 g), chopped shoots x 4 feeds/day (22.24 g), whole leaves x 5 feeds/day (22.19 g), whole shoots x 3 feeds/day (22.14 g), whole leaves x 4 feeds/day (22.07 g) and chopped shoots x 3 feeds/day (22.02 g) at same level of N. However, the combination N @ 75 kg/ha/yr x whole leaves x 3 feeds/day stood least with regard to cocoon weight (17.11 g) (Table 4.15 and Plate 4.1).

4.4.2.2 Shell weight

Nitrogen level

Silkworm receiving mulberry fertilized with N @ 125 kg/ha/yr recorded higher shell weight of 4.376 g/10 shells. It was followed by 100 (4.087 g) and 75 kg/ha/yr (3.094g) with marked differences among them.

Feeding method

Method of feeding silkworms influenced the shell weight, highest being with whole shoots (3.976 g) as compared to chopped shoots (3.861 g) and whole leaves (3.721 g).

Feeding frequency

Cocoon shells formed by silkworms fed on mulberry at a frequency of 5 feeds/day was found superior in respect of shell weight (3.984 g). Regime of 4 feeds a day (3.898 g) was next best and 3 feeds/day (3.676 g) was inferior (Table 4.15).

Nitrogen level x Feeding method

Silkworms fed on mulberry whole shoots raised at 125 kg N/ha/yr registered higher weight of shells (4.418 g) along with chopped shoots (4.376 g) and whole leaves (4.334 g). Nitrogen @ 100 kg/ha/yr x whole shoots (4.162 g), chopped shoots (4.101 g) and whole leaves (4.000 g) were found moderate for shell weight. The combination of N @ 75 kg/ha/yr x whole leaves yielded the least weight of shells (2.829 g).

Nitrogen level x Feeding frequency

Feeding of silkworms 5 times a day in combination with N @ 125 kg/ha/yr gave higher weight of shells (4.416 g), 4 (4.390 g) and 3 feeds/day (4.322 g) at same level of N. It was lower for N @ 75 kg/ha/yr x 3 feeds/day (2.742 g) (Table 4.15).

Feeding method x Feeding frequency

Worms which received mulberry through whole shoots 5 times a day (4.080 g), whole shoots x 4 times/day (4.040 g) and chopped shoots x 5 times/day (4.000 g) registered higher shell weight. The shell weight of 3.565 g obtained with whole leaves x 3 feeds/day was the least.

Nitrogen level x Feeding method x Feeding frequency

Significant differences were obvious among N level, feeding method and frequency with respect to shell weight, highest being with 125 kg N/ha/yr x whole shoots x 5 feeds/day (4.452 g) together with whole shoots x 4 feeds/day (4.437 g), chopped shoots x 5 feeds/day (4.414 g), chopped shoots x 4 feeds/day (4.398 g), whole leaves x 5 feeds/day (4.383 g), whole shoots x 3 feeds/day (4.365 g), whole leaves x 4 feeds/day (4.336 g), chopped shoots x 3 feeds/day (4.317 g) and whole leaves x 3 feeds/day (4.283 g) at same level of N. However, it was least for 75 kg N/ha/yr x whole leaves x 3 feeds/day (2.518 g) (Table 4.15).

4.4.2.3 Shell ratio

Nitrogen level

Shell ratio i.e., ratio of shell to cocoon expressed in percentage was markedly influenced by feeding silkworms with mulberry raised at varied N levels. It was higher with 125 kg N/ha/yr (19.74%) and 100 kg N/ha/yr (19.12%). However, lower shell ratio was found with 75 kg N/ha/yr (16.98%).

Feeding method

Marked variation was evident with feeding methods for shell ratio, significantly higher ratio being with whole shoots (19.04%) as compared to chopped shoots (18.74%) and whole leaves (18.33%) feeding.

Feeding frequency

Schedule of feeding silkworms showed significant variations with regard to shell ratio. The frequency of 5 feeds/day recorded higher shell ratio of 19.07 per cent when compared to 4 (18.84%) and 3 feeds/day (18.20%) (Table 4.15).

Nitrogen level x Feeding method

Shell ratio was higher with whole shoots raised at 125 kg/ha/yr (19.82%) together with chopped shoots (19.72%) and whole leaves (19.65%) at same level of N. Nitrogen application @ 100 kg/ha/yr found moderate with same sequence of feeding method as above. However, it was lower with 75 kg/ha/yr x whole leaves (16.01%).

Nitrogen level x Feeding frequency

The feeding sequence of 5, 4 and 3 times a day at 125 kg/ha/yr recorded significantly higher shell ratio (19.82, 19.76 and 19.62%) over 100 (19.29, 19.18 and 18.86%) and 75 kg/ha/yr (17.90, 17.30 and 15.65%) (Table 4.15).

Feeding method x Feeding frequency

The combination of whole shoots x 5 feeds/day recorded highest shell ratio of 19.29 per cent. It was closely followed by whole shoots x 4 feeds/day (19.21%) and chopped shoots x 5 feeds/day (19.12%). However, lowest shell ratio was found with whole leaves x 3 feeds/day (17.86%).

Table 4.15 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on cocoon weight, shell weight and shell ratio

Parameters		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
Cocoon Weight (g/10)	N_1	18.22	M_1	20.29	F_1	20.19	N_1	17.67	18.79	18.19	N_1	17.52	18.38	18.76	M_1	19.96	20.28	20.63	M_1	17.11	17.64	18.26	20.85	21.14	21.44	21.91	22.07	22.19
	N_2	21.38	M_2	20.88	F_2	20.69	N_2	21.14	21.58	21.42	N_2	21.02	21.48	21.64	M_2	20.47	21.03	21.14	M_2	18.07	19.04	19.25	21.20	21.74	21.80	22.14	22.32	22.37
	N_3	22.17	M_3	20.60	F_3	20.89	N_3	22.05	22.28	22.18	N_3	22.02	22.21	22.28	M_3	20.14	20.75	20.91	M_3	17.37	18.45	18.76	21.02	21.56	21.69	22.02	22.24	22.29
S.Em ±		0.049		0.049		0.049			0.084				0.084				0.084							0.250				
C.D. at 5%		0.138		0.138		0.138			0.239				0.239				0.239							0.410				
Shell Weight (g/10)	N_1	3.094	M_1	3.721	F_1	3.676	N_1	2.829	3.349	3.105	N_1	2.742	3.181	3.359	M_1	3.565	3.726	3.871	M_1	2.518	2.839	3.130	3.895	4.003	4.101	4.283	4.336	4.383
	N_2	4.087	M_2	3.976	F2	3.898	N_2	4.000	4.162	4.101	N_2	3.965	4.122	4.175	M_2	3.808	4.040	4.080	M_2	3.019	3.473	3.554	4.039	4.211	4.235	4.365	4.437	4.452
	N_3	4.376	M_3	3.861	F_3	3.984	N_3	4.334	4.418	4.376	N_3	4.322	4.390	4.416	M_3	3.656	3.927	4.000	M_3	2.690	3.230	3.394	3.960	4.152	4.190	4.317	4.398	4.414
S.Em ±		0.023		0.023		0.023			0.040				0.040				0.040							0.122				
C.D. at 5%		0.065		0.065		0.065			0.115				0.115				0.115							0.206				
Shell Ratio (%)	N_1	16.98 (24.29)	M_1	18.33 (25.22)	F_1	18.20 (25.10)	N_1	16.01 (23.56)	17.82 (24.94)	17.06 (24.36)	N_1	15.65 (23.27)	17.30 (24.55)	17.90 (25.03)	M_1	17.86 (24.80)	18.37 (25.25)	18.76 (25.60)	M_1	14.71 (22.55)	16.09 (23.65)	17.16 (24.47)	18.68 (25.61)	18.94 (25.80)	19.13 (25.94)	19.55 (26.24)	19.65 (26.31)	19.75 (26.39)
	N_2	19.12 (25.92)	M_2	19.04 (25.81)	F_2	18.84 (25.64)	N_2	18.92 (25.78)	19.28 (26.05)	19.14 (25.94)	N_2	18.86 (25.74)	19.18 (25.98)	19.29 (26.06)	M_2	18.60 (25.45)	19.21 (25.96)	19.29 (26.03)	M_2	16.67 (24.10)	18.24 (25.28)	18.46 (25.45)	19.05 (25.88)	19.37 (26.11)	19.43 (26.15)	19.72 (26.36)	19.88 (26.48)	19.90 (26.49)
	N_3	19.74 (26.38)	M_3	18.74 (25.56)	F_3	19.07 (25.84)	N_3	19.65 (26.31)	19.82 (26.45)	19.72 (26.37)	N_3	19.62 (26.29)	19.76 (26.40)	19.82 (26.43)	M_3	18.15 (25.06)	18.92 (25.72)	19.12 (25.89)	M_3	15.48 (23.17)	17.50 (24.73)	18.09 (25.17)	18.84 (25.72)	19.26 (26.03)	19.32 (26.07)	19.60 (26.28)	19.78 (26.41)	19.80 (26.42)
S.Em ±		0.029		0.029		0.029			0.050				0.050				0.050							0.150				
C.D. at 5%		0.081		0.081		0.081			0.140				0.140				0.140							0.240				

Figures in the parentheses are angular transformed values

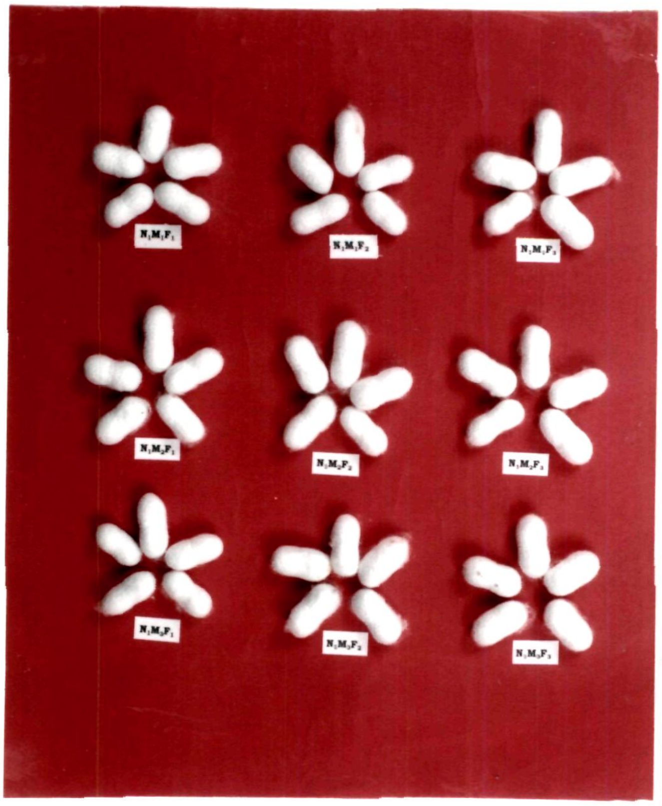
N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

Plate 4.1: Cocoons obtained from mulberry raised with different nitrogen (CAN) levels, methods and frequencies of feeding

Nitrogen level	Feeding method	Feeding frequency
N_1= 75 kg/ha/year	M_1= Whole leaves	F_1= 3 feeds/day
N_2= 100 kg/ha/year	M_2= Whole shoots	F_2= 4 feeds/day
N_3= 125 kg/ha year	M_3= Chopped shoots	F_3=5 feeds/day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$N_1M_1F_2$
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$N_1M_2F_2$
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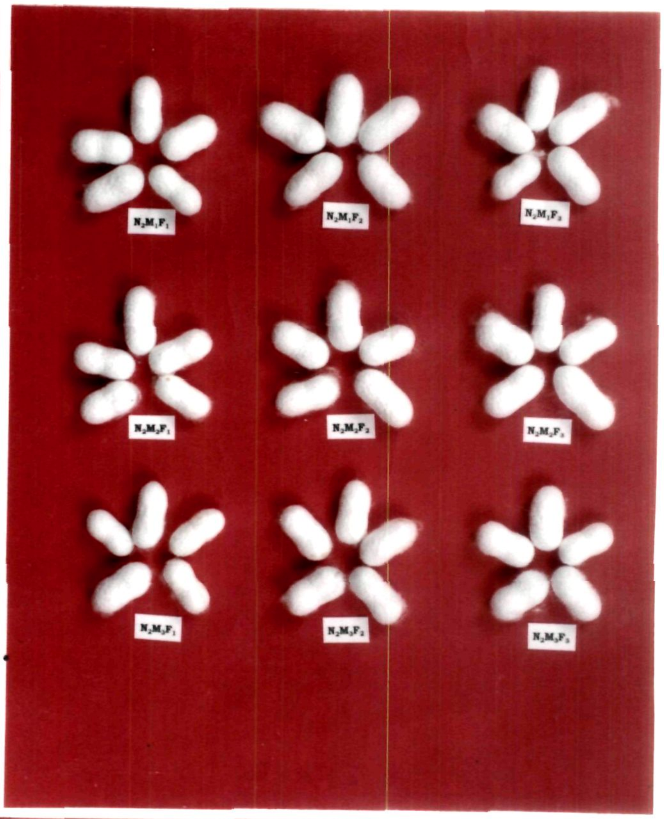
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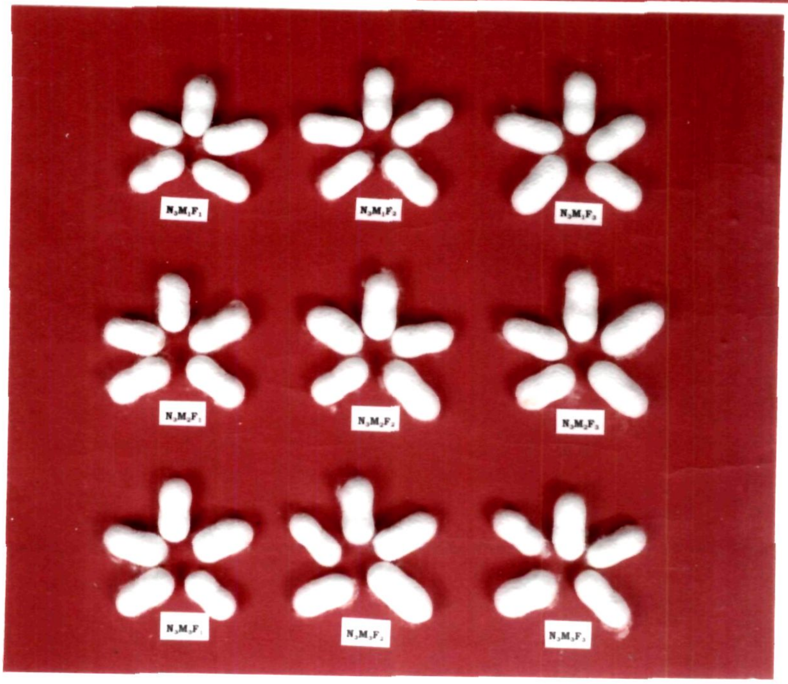
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$N_3M_1F_3$
$N_3M_2F_1$
$N_3M_2F_2$
$N_3M_2F_3$
$N_3M_3F_1$
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Nitrogen level x Feeding method x Feeding frequency

Statistical variations were found among N levels, methods and frequencies of feeding in respect of shell ratio. It was higher with 125 kg N/ha/yr x whole shoots x 5 feeds/day (19.90%) along with whole shoots x 4 feeds/day (19.88%), chopped shoots x 5 feeds/day (19.80%), chopped shoots x 4 feeds/day (19.78%), whole leaves x 5 feeds/day (19.75%), whole shoots x 3 feeds/day (19.72%), whole leaves x 4 feeds/day (19.65%) and chopped shoots x 3 feeds/day (19.60%) at same level of N. Similar trend was observed at 100 and 75 kg N/ha/yr with similar method and frequency of feeding as above with regard to shell ratio. Combination of 75 kg N/ha/yr x whole shoots x 3 feeds/day stood least for the shell ratio of 14.71 per cent (Table 4.15).

4.4.2.4 Single cocoon Filament length

Nitrogen level

Cocoons formed from silkworms fed with mulberry leaf raised by application of varied N levels recorded significantly longer single cocoon filament of 1129 m at 125 kg N/ha/yr over 100 (1038 m) and 75 kg/ha/yr (848 m).

Feeding method

Among the feeding methods, cocoon filament was longer (1028 m) in the case of cocoons obtained by feeding the silkworms with whole shoots. It was followed by chopped shoots (1004 m) and was shortest with whole leaves (982 m).

Feeding frequency

Rearing of silkworms at a feeding frequency of 5 feeds/day recorded longest filament (1028 m) together with 4 feeds/day (1011 m) and it was shortest with 3 feeds/day (975 m) (Table 4.16).

Nitrogen level x Feeding method

Rearing of silkworms with whole shoots obtained by the fertilization of 125 kg N/ha/yr yielded longer filament of 1147 m along with chopped shoots (1129 m) at same level of N. Nitrogen @ 125 kg/ha/yr x whole leaves (1111 m) ; N @ 100 kg/ha/yr x whole shoots (1058 m), chopped shoots (1036 m) and whole leaves (1020 m) ; N @ 75 kg/ha/yr x whole shoots (881 m) and chopped shoots (848 m) registered moderate filament length. The combination of N @ 75 kg/ha/yr x whole leaves registered shorter filament (815 m).

Nitrogen level x Feeding frequency

Silkworms that received mulberry 5 feeds/day in combination with 125 kg N/ha/yr yielded longer filament of 1148 m along with those provided 4 feeds/day (1134 m) at same level of N. However, it was shorter with 75 kg N/ha/yr x 3 feeds/day (807 m) (Table 4.16).

Feeding method x Feeding frequency

Silkworms fed with whole shoots at a feeding sequence of 5 and 4 feeds/day recorded longer filament of 1054 and 1040 m, closely followed by chopped shoots x 5 feeds/day (1027 m). Whole leaves recorded shorter filament of 962 m with 3 feeds/day.

Nitrogen level x Feeding method x Feeding frequency

Marked variations were exhibited by method and frequency of feeding mulberry raised at varied N levels. Silkworms fed with whole shoots of mulberry raised with 125 kg N/ha/yr in combination with 5 feeds/day recorded longer filament of 1169 m along with whole shoots x 4 feeds/day (1154 m), chopped shoots x 5 feeds/day (1146 m), chopped shoots x 4 feeds/day (1140 m), whole leaves x 5 feeds/day (1131 m) and whole shoots x 3 feeds/day (1119 m) at same level of N. However, shortest filament was registered in the combination of 75 kg N/ha/yr x whole leaves x 3 feeds/day (789 m) (Table 4.16 and Fig.4.5).

4.4.2.5 Denier

The method and frequency of feeding and their combination did not influence the size of cocoon filament (denier).

Nitrogen level

Marked differences existed with regard to denier with feeding of mulberry to silkworm raised at different levels of N. Thinner filament was noticed with the application of N @ 125 kg/ha/yr (2.46) as compared to 100 kg N/ha/yr (2.50). Denier was more with 75 kg N/ha/yr (2.54).

Nitrogen level x Feeding method

Silkworms fed mulberry through whole shoots with a combination of 125 kg N/ha/yr recorded less denier (2.45) together with chopped shoots (2.46) and whole leaves (2.47) at same level of N ; 100 kg N/ha/yr x whole shoots (2.49), chopped shoots (2.50) and

Table 4.16 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on single cocoon filament length and denier

Parameters	N		M		F		N x M				N x F				M x F				N x M x F									
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
Single cocoon filament length (m)	N_1	848	M_1	982	F_1	975	N_1	815	881	848	N_1	807	857	880	M_1	962	980	1004	M_1	789	811	845	1004	1020	1037	1094	1109	1131
	N_2	1038	M_2	1028	F_2	1011	N_2	1020	1058	1036	N_2	1014	1043	1057	M_2	991	1040	1054	M_2	830	901	912	1026	1067	1082	1119	1154	1169
	N_3	1129	M_3	1004	F_3	1028	N_3	1111	1147	1129	N_3	1105	1134	1148	M_3	972	1015	1027	M_3	802	861	883	1014	1044	1052	1102	1140	1146
S.Em ±		6.320		6.320		6.320			10.95				10.95				10.95							32.84				
C.D. at 5%		17.92		17.92		17.92			31.04				31.04				31.04							53.75				
Denier	N_1	2.54	M_1	2.50	F_1	2.51	N_1	2.54	2.53	2.54	N_1	2.55	2.53	2.53	M_1	2.51	2.51	2.50	M_1	2.55	2.54	2.54	2.51	2.51	2.50	2.48	2.47	2.46
	N_2	2.50	M_2	2.49	F2	2.49	N_2	2.50	2.49	2.50	N_2	2.51	2.50	2.49	M_2	2.50	2.48	2.48	M_2	2.54	2.52	2.52	2.50	2.49	2.48	2.46	2.44	2.44
	N_3	2.46	M_3	2.50	F_3	2.49	N_3	2.47	2.45	2.46	N_3	2.47	2.45	2.45	M_3	2.51	2.49	2.49	M_3	2.55	2.53	2.53	2.51	2.50	2.49	2.47	2.45	2:45
S.Em ±		0.011		0.011		0.011			0.019				0.019				0.019							0.060				
C.D. at 5%		0.031		-		-			0.054				0.054				-							0.090				

N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

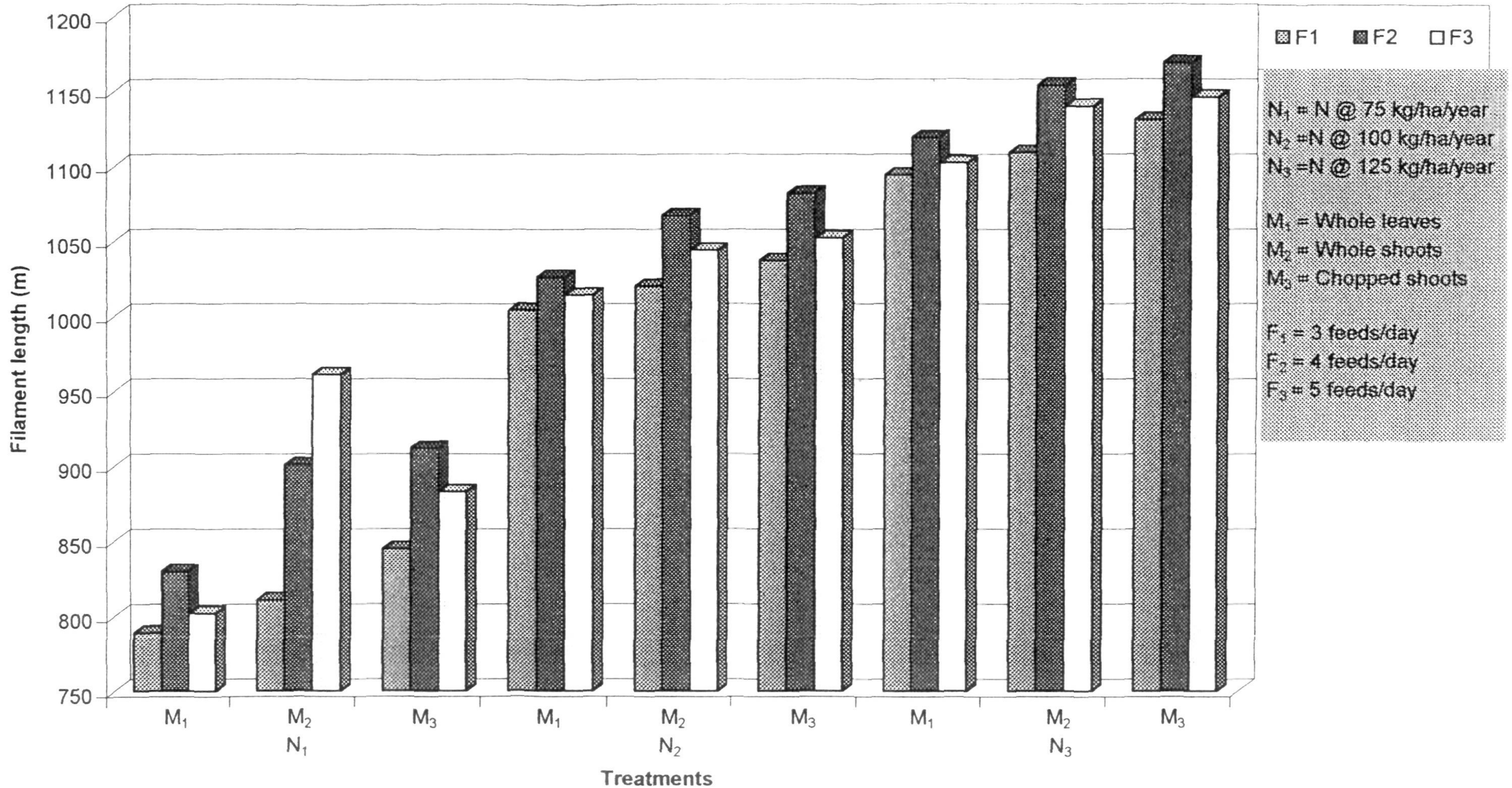

Fig. 4. 5 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on single cocoon filament length

whole leaves (2.50). Filament was thicker with 75 kg N/ha/yr x whole leaves (2.54) (Table 4.16).

Nitrogen level x Feeding frequency

Feeding of silkworms 5 times a day with mulberry raised by applying N @ 125 kg/ha/yr recorded less denier (2.45) along with 4 (2.45) and 3 feeds/day (2.47) at same level of N. However, in the remaining treatment combinations it ranged between 2.49 to 2.55.

Nitrogen level x Feeding method x Feeding frequency

The interaction of N @ 125 kg/ha/yr x whole shoots x 5 and 4 feeds/day recorded thinner filament denier of 2.44 along with chopped shoots x 5 and 4 feeds/day (2.45), whole shoots x 3 feeds/day (2.46), whole leaves x 5 feeds/day (2.46), whole leaves x 4 feeds/day (2.47), chopped shoots x 3 feeds/day (2.47) and whole leaves x 3 feeds/day (2.48) at same level of N. However, more denier was noticed with N @ 75 kg/ha/yr x whole leaves x 3 feeds/day (2.55). In the remaining treatment combinations the denier varied from 2.49 to 2.54 (Table 4.16).

4.4.2.6 Fibroin

The main effects viz., feeding method and feeding frequency and first order interaction effect of method and frequency of feeding showed non-significant with regard to fibroin content.

Nitrogen level

Silkworms fed on mulberry fertilized with different levels of N did influence the secretion of fibroin with content being higher at 125 kg N/ha/yr (77.99%) along with 100 kg N/ha/yr (77.06%) and it was lower with 75 kg N/ha/yr (74.81%).

Nitrogen level x Feeding method

Varied levels of N fertilization to mulberry and inturn feeding of such leaves to silkworms caused higher content of fibroin and it was highest with the combination of N @ 125 kg/ha/yr x whole shoots (78.13%), chopped shoots (78.01%) and whole leaves (77.83%) ; 100 kg N/ha/yr x whole shoots (77.24%), chopped shoots (77.04%) and whole leaves (76.91%) at same level of N. However, it was lower with 75 kg N/ha/yr x whole leaves (74.50%) (Table 4.17).

Nitrogen level x Feeding frequency

The combination of N level and feeding frequency did influence significantly the secretion of fibroin. Feeding of silkworms at a frequency of 5, 4 and 3 times a day recorded higher content of fibroin (78.17, 78.05 and 77.75%) at 125 kg N/ha/yr. The same was closely followed by 100 kg N/ha/yr (77.22, 77.11 and 76.86%) and it was lower with 75 kg N/ha/yr (75.11, 74.93 and 74.40%).

Nitrogen level x Feeding method x Feeding frequency

The interaction of N @ 125 kg/ha/yr x whole shoots x 5 feeds/day recorded higher fibroin content (78.29%) together with whole shoots x 4 feeds/day (78.21%), chopped shoots x 5 feeds/day (78.17%), chopped shoots x 4 feeds/day (78.12%), whole leaves x

5 feeds/day (78.06%), whole shoots x 3 feeds/day (77.90%), whole leaves x 4 feeds/day (77.81%), chopped shoots x 3 feeds/day (77.75%) and whole leaves x 3 feeds/day (77.61%) at same level of N. However, it was lowest with N @ 75 kg/ha/yr x whole leaves x 3 feeds/day (74.14%) (Table 4.17).

4.4.2.7 Sericin

Nitrogen level

Silkworms that received mulberry leaves fertilized with varied levels of N influenced on secretion of sericin. Significantly lower percentage of sericin was noticed with N @ 125 kg/ha/yr (20.94%) over 100 (21.82%) and 75 kg/ha/yr (23.99%) with statistical differences among them.

Feeding method

Method of offering mulberry to silkworms also influenced the secretion of sericin, with least values for whole shoots (22.06%) and chopped shoots (22.17%) as compared to whole leaves (22.51%).

Feeding frequency

Silkworms provided with mulberry 5 times a day registered the least content of sericin (22.05%) along with 4 times a day (22.18%) and it was highest with 3 feeds a day (22.52%) (Table 4.17).

Nitrogen level x Feeding method

The batch of silkworms fed with whole shoots raised at N level of 125 kg/ha/yr recorded lowest percentage of sericin (20.75%) together with chopped shoots (20.89%) at same level of N. However, the worms fed with whole shoots (23.79%), chopped shoots (23.79%) and whole leaves (24.38%) raised at N @ 75 kg/ha/yr registered higher content of sericin.

Nitrogen level x Feeding frequency

Number of feeds provided per day in combination with N levels did influence the percentage of sericin and it was lowest with 5, 4 and 3 feeds/day at 125 kg N/ha/yr (20.74, 20.82 and 21.26%) over 100 (21.67, 21.78 and 22.02%) and 75 kg N/ha/yr (23.75, 23.94 and 24.27%) (Table 4.17).

Feeding method x Feeding frequency

The difference in respect of sericin content between method and frequency of feeding was significant. It was lowest with whole shoots x 5 feeds/day (21.86%), whole shoots x 4 feeds/day (21.97%), chopped shoots x 5 feeds/day (22.07%) and chopped shoots x 4 feeds/day (22.10%). However, the percentage of sericin was highest with whole leaves x 3 feeds/day (22.84%).

Nitrogen level x Feeding method x Feeding frequency

Silkworms reared on whole shoots at 5 feeds/day in combination with N @ 125 kg/ha/yr noticed least value for sericin (20.60%) together with whole shoots x 4 feeds/day (20.63%), chopped shoots x 4 feeds/day (20.74%), chopped shoots x 5 feeds/day (20.77%), whole leaves x 5 feeds/day (20.85%), whole shoots x 3 feeds/day (21.02%) and whole leaves x 4 feeds/day (21.09%). It was highest with N @ 75 kg/ha/yr x whole leaves x 3 feeds/day (24.77%).

Table 4.17 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on fibroin and sericin contents

Param-Eters		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
	N_1	74.81 (59.89)	M_1	76.41 (60.97)	F_1	76.34 (60.92)	N_1	74.50 (59.68)	75.09 (60.07)	74.85 (59.92)	N_1	74.40 (59.61)	74.93 (59.97)	75.11 (60.09)	M_1	76.16 (60.80)	76.42 (60.98)	76.65 (61.13)	M_1	74.14 (59.45)	74.53 (59.70)	74.83 (59.90)	76.74 (61.18)	76.92 (61.30)	77.06 (61.40)	77.61 (61.78)	77.81 (61.92)	78.06 (62.09)
Fibroin (%)	N_2	77.06 (61.40)	M_2	76.82 (61.24)	F_2	76.70 (61.16)	N_2	76.91 (61.29)	77.24 (61.52)	77.04 (61.39)	N_2	76.86 (61.26)	77.11 (61.43)	77.22 (61.51)	M_2	76.53 (61.05)	76.91 (61.30)	77.03 (61.38)	M_2	74.67 (59.80)	75.22 (60.16)	75.37 (60.26)	77.01 (61.36)	77.30 (61.56)	77.42 (61.64)	77.90 (61.98)	78.21 (62.19)	78.29 (62.25)
	N_3	77.99 (62.04)	M_3	76.64 (61.12)	F_3	76.84 (61.25)	N_3	77.83 (61.93)	78.13 (62.14)	78.01 (62.05)	N_3	77.75 (61.87)	78.05 (62.08)	78.17 (62.17)	M_3	76.32 (60.90)	76.76 (61.20)	76.83 (61.25)	M_3	74.38 (59.60)	75.05 (60.05)	75.13 (60.10)	78.83 (61.24)	77.11 (61.43)	77.19 (61.49)	77.75 (61.87)	78.12 (62.13)	78.17 (62.16)
S.Em ±		0.275		0.275		0.275			0.477				0.477				0.477							1.430				
C.D. at 5%		0.781		-		-			1.353				1.353				-							2.340				
	N_1	23.99 (29.32)	M_1	22.51 (28.32)	F_1	22.52 (28.32)	N_1	24.38 (29.59)	23.79 (29.19)	23.79 (29.19)	N_1	24.27 (29.51)	23.94 (29.29)	23.75 (29.17)	M_1	22.84 (28.54)	22.47 (28.29)	22.23 (28.12)	M_1	24.77 (29.85)	24.35 (29.57)	24.02 (29.35)	22.15 (28.08)	21.98 (27.96)	21.82 (27.85)	21.59 (27.69)	21.09 (27.34)	20.85 (27.17)
Sericin (%)	N_2	21.82 (27.85)	M_2	22.06 (28.00)	F2	22.18 (28.09)	N_2	21.98 (27.96)	21.64 (27.72)	21.84 (27.86)	N_2	22.02 (27.98)	21.78 (27.82)	21.67 (27.74)	M_2	22.36 (28.21)	21.97 (27.94)	21.86 (27.86)	M_2	24.21 (29.47)	23.65 (29.10)	23.52 (29.01)	21.85 (27.87)	21.62 (27.71)	21.45 (27.59)	21.02 (27.29)	20.63 (27.01)	20.60 (26.99)
	N_3	20.94 (27.23)	M_3	22.17 (28.08)	F_3	22.05 (28.00)	N_3	21.18 (27.40)	20.75 (27.10)	20.89 (27.20)	N_3	21.26 (27.45)	20.82 (27.15)	20.74 (27.09)	M_3	22.35 (28.20)	22.10 (28.03)	22.07 (28.01)	M_3	23.83 (29.22)	23.81 (29.21)	23.72 (29.14)	22.05 (28.01)	21.75 (27.80)	21.73 (27.78)	21.16 (27.39)	20.74 (27.09)	20.77 (27.11)
S.Em ±		0.046		0.046		0.046			0.079				0.079				0.079							0.240				
C.D. at 5%		0.130		0.130		0.130			0.225				0.225				0.225							0.390				

Figures in the parentheses are angular transformed values

N= Nitrogen level : N_1= 75 kg/ha/year, N_2= 100 kg/ha/year, N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves, M_2 = Whole Shoots, M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day, F_2 = 4 feeds/day, F_3 = 5 feeds/day

However, in the remaining treatment combinations it varied from 21.16 to 24.35 per cent (Table 4.17).

4.4.3 GRAINAGE PARAMETERS

The data on the influence of method and frequency of feeding mulberry fertilized with different levels of N on grainage performance are presented in Table 4.18 and 4.19.

4.4.3.1 Rate of pupation

Nitrogen level

Rate of pupation was influenced by N levels, significantly higher pupation being with application of N @ 125 kg/ha/yr (96.13%) compared to 100 (93.89%) and 75 kg/ha/yr (88.24%) with clear cut variation among them.

Feeding method

Feeding methods exhibited marked variations with regard to rate of pupation and highest was recorded with whole shoots (93.53%) and chopped shoots (92.69%) and the same was lowest with whole leaves feeding (92.04%).

Feeding frequency

Schedule of feeding silkworms did influence the rate of pupation and it was higher with 5 feeds/day (93.44%) along with 4 feeds/day (92.98%) and it was least with 3 feeds/day (91.84%) (Table 4.18).

Nitrogen level x Feeding method

The combination of N @ 125 kg/ha/yr x whole shoots recorded higher pupation rate of 96.60 per cent together with chopped shoots (96.20%) and whole leaves (95.60%) at same level of N. Next in the order were whole shoots (94.40%), chopped shoots (93.87%) and whole leaves (93.40%) at 100 kg N/ha/yr. The combination of 75 kg N/ha/yr x whole leaves recorded the least rate of pupation (87.13%).

Nitrogen level x Feeding frequency

Feeding of worms 5, 4 and 3 times a day resulted in higher rate of pupation at 125 kg N/ha/yr (96.67, 96.33 and 95.40%) over 100 (94.33, 94.00 and 93.33%) and 75 kg/ha/yr (89.33, 88.60 and 86.80%) (Table 4.18)

Feeding method x Feeding frequency

Whole shoot feeding with a frequency of 5 times a day caused highest pupation of 94.00 per cent together with whole shoots x 4 feeds/day (93.87%), chopped shoots x 5 feeds/day (93.33%), chopped shoots x 4 feeds/day (93.20%), whole leaves x 5 feeds/day (93.00%), whole shoots x 3 feeds/day (92.73%) and whole leaves x 4 feeds/day (91.87%). However, it was lowest with whole leaves x 3 feeds/day (91.27%).

Nitrogen level x Feeding method x Feeding frequency

The second order interaction showed significant in respect of pupation rate (96.80%) with the combination of N @ 125 kg/ha/yr x whole shoots x 5 and 4 feeds/day and chopped shoots x 5 feeds/day. The pupation rate in other treatment combinations ranged from

86.00 to 96.60 per cent, the lowest being with 75 kg N/ha/yr x whole leaves x 3 feeds/day (Table 4.18).

4.4.3.2 Pupal weight

Nitrogen level

Significantly higher pupal weight was recorded in respect of worms fed on mulberry fertilized with N @ 125 kg/ha/yr (17.71 g/10 pupae) over 100 (17.19 g) and 75 kg/ha/yr (15.04 g) with marked differences existing among them.

Feeding method

Among the methods of feeding, the worms fed on whole shoots resulted in significantly higher pupal weight (16.81 g), followed by chopped shoots (16.65 g) and it was lower with whole leaves (16.48 g) feeding.

Feeding frequency

Silkworms fed with a frequency of 5 times a day recorded higher pupal weight (16.82 g), followed by 4 times a day (16.71 g) and weight was least with 3 feeds/day (16.42 g) (Table 4.18).

Nitrogen level x Feeding method

The combination of N @ 125 kg/ha/yr x whole shoots contributed for higher weight of pupae (17.78 g) together with chopped shoots (17.72 g) and whole leaves (17.64 g) at same level of N. However, it was lower with N @ 75 kg/ha/yr x whole leaves (14.76 g).

Nitrogen level x Feeding frequency

Silkworms provided mulberry 5, 4 and 3 times a day raised at N @ 125 kg/ha/yr yielded higher pupal weight (17.77, 17.74 and 17.63 g, respectively). It was lower in the combinations of N @ 75 kg/ha/yr x 5 (15.31 g), 4 (15.11 g) and 3 times a day (14.69 g) at same level of N (Table 4.18).

Feeding method x Feeding frequency

Silkworms that were offered whole shoots 5 times a day were found best for pupal weight (16.98 g) together with chopped shoots x 4 feeds/day (16.94 g) and whole shoots x 4 feeds/day (16.90 g). Pupal weight was least with whole leaves x 3 feeds/day (16.29 g).

Nitrogen level x Feeding method x Feeding frequency

The interaction of N @ 125 kg N/ha/yr x whole shoots x 5 feeds/day recorded higher pupal weight of 17.84 g along with whole shoots x 4 feeds/day (17.79 g), chopped shoots x 5 feeds/day (17.77 g), chopped shoots x 4 feeds/day (17.73 g), whole leaves x 5 feeds/day (17.71 g), whole shoots x 3 feeds/day (17.70 g), whole leaves x 4 feeds/day (17.69 g) and chopped shoots x 3 feeds/day (17.67 g) at same level of N. The trend was similar at 100 and 75 kg N/ha/yr. However, pupal weight was lower with the combination of 75 kg N/ha/yr x whole leaves x 3 feeds/day (14.52 g) (Table 4.18).

4.4.3.3 Pupal duration

Method and frequency of feeding and their interaction effects and second order interaction of N level, feeding method and feeding

Table 4.18 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on rate of pupation, pupal weight and pupal duration

Parameters		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
Rate of pupation (%)	N_1	88.24 (70.03)	M_1	92.04 (74.12)	F_1	91.84 (73.92)	N_1	87.13 (69.03)	89.60 (71.27)	88.00 (69.79)	N_1	86.80 (68.73)	88.60 (70.34)	89.33 (71.01)	M_1	91.27 (73.27)	91.87 (73.90)	93.00 (75.21)	M_1	86.00 (68.06)	87.00 (68.88)	88.40 (70.14)	93.00 (74.72)	93.00 (74.74)	94.20 (76.23)	94.80 (77.02)	95.60 (78.06)	96.40 (79.25)
	N_2	93.89 (75.82)	M_2	93.53 (75.84)	F_2	92.98 (75.22)	N_2	93.40 (75.23)	94.40 (76.46)	93.87 (75.78)	N_2	93.33 (75.13)	94.00 (75.97)	94.33 (76.36)	M_2	92.73 (74.94)	93.87 (76.24)	94.00 (76.33)	M_2	88.00 (69.76)	90.20 (71.80)	90.60 (72.24)	94.00 (75.95)	94.60 (76.75)	94.60 (76.69)	96.20 (79.10)	96.80 (80.17)	96.80 (80.07)
	N_3	96.13 (79.08)	M_3	92.69 (74.97)	F_3	93.44 (75.79)	N_3	95.60 (78.11)	96.60 (79.78)	96.20 (79.33)	N_3	95.40 (77.90)	96.33 (79.35)	96.67 (79.99)	M_3	91.53 (73.56)	93.20 (75.52)	93.33 (75.82)	M_3	86.40 (68.38)	88.60 (70.32)	89.00 (70.65)	93.00 (74.92)	94.40 (76.43)	94.20 (76.17)	95.20 (77.57)	96.60 (79.80)	96.80 (80.63)
S.Em ±		0.505		0.505		0.505			0.875				0.875				0.875							2.630				
C.D. at 5%		1.433		1.433		1.433			2.481				2.481				2.481							4.300				
Pupal weight (g)	N_1	15.04	M_1	16.48	F_1	16.42	N_1	14.76	15.34	15.01	N_1	14.69	15.11	15.31	M_1	16.29	16.48	16.66	M_1	14.52	14.72	15.03	16.84	17.04	17.23	17.52	17.69	17.71
	N_2	17.19	M_2	16.81	F2	16.71	N_2	17.04	17.32	17.23	N_2	16.95	17.27	17.37	M_2	16.56	16.90	16.98	M_2	14.93	15.48	15.62	17.06	17.43	17.47	17.70	17.79	17.84
	N_3	17.71	M_3	16.65	F_3	16.82	N_3	17.64	17.78	17.72	N_3	17.63	17.74	17.77	M_3	16.41	16.94	16.81	M_3	14.61	15.14	15.27	16.94	17.34	17.40	17.67	17.73	17.77
S.Em ±		0.029		0.029		0.029			0.051				0.051				0.051							0.150				
C.D. at 5%		0.083		0.083		0.083			0.144				0.144				0.144							0.250				
Pupal duration (days)	N_1	12.69	M_1	12.06	F_1	12.11	N_1	12.83	12.58	12.67	N_1	12.92	12.58	12.58	M_1	12.17	12.00	12.00	M_1	13.00	12.75	12.75	12.00	12.00	12.00	11.50	11.25	11.25
	N_2	11.89	M_2	11.83	F_2	11.83	N_2	12.00	11.83	11.83	N_2	12.00	11.83	11.83	M_2	12.00	11.75	11.75	M_2	12.75	12.50	12.50	12.00	11.75	11.75	11.25	11.00	11.00
	N_3	11.19	M_3	11.89	F_3	11.83	N_3	11.33	11.08	11.17	N_3	11.42	11.08	11.08	M_3	12.17	11.75	11.75	M_3	13.00	12.50	12.50	12.00	11.75	11.75	11.50	11.00	11.00
S.Em ±		0.284		0.284		0.284			0.492				0.492				0.492							1.480				
C.D. at 5%		0.806		-		-			1.395				1.395				-							-				

Figures in the parentheses are angular transformed values

N= Nitrogen level : N_1= 75 kg/ha/year, N_2= 100 kg/ha/year, N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves, M_2 = Whole Shoots, M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day, F_2 = 4 feeds/day, F_3 = 5 feeds/day

frequency were found to be non-significant with regard to pupal duration.

Nitrogen level

Application of 125 kg N/ha/yr registered shorter pupal duration of 11.19 days along with that of 100 kg N/ha/yr (11.89 days) and it was longer with 75 kg N/ha/yr (12.69 days) (Table 4.18).

Nitrogen level x Feeding method

Rearing of silkworms with whole shoots raised with application of N @ 125 kg/ha/yr recorded the least pupation of 11.08 days along with chopped shoots (11.17 days) and whole leaves (11.33 days) ; N @ 100 kg/ha/yr x whole shoots (11.83 days), chopped shoots (11.83 days) and whole leaves (12.00 days) at same level of N. However, the duration was longest with 75 kg N/ha/yr x whole leaves (12.83 days).

Nitrogen level x Feeding frequency

The interactions of N @ 125 kg/ha/yr x 5 and 4 feeds/day recorded the least pupal duration (11.08 days) together with whole leaves (11.42 days) at same level of N. The treatment N @ 75 kg/ha/yr x whole leaves resulted in longest duration (12.92 days) (Table 4.18).

4.4.3.4 Rate of moth emergence

Non-significant results were observed among method and frequency of feeding and their interactions with regard to moth emergence.

Nitrogen level

The extent of moths emerged from pupae resulting from feeding worms with mulberry raised at different N levels was significant. It was higher with 125 kg N/ha/yr (95.98%), followed by 100 (94.07%) and 75 kg N/ha/yr (88.11%) (Table 4.19).

Nitrogen level x Feeding method

Method of feeding silkworms with mulberry raised at varied levels of N did influence the moth emergence, which was higher with N @ 125 kg/ha/yr x whole shoots (96.27%), chopped shoots (95.93%) and whole leaves (95.73%) at same level of N. Further, the combinations whole shoots (94.53%), chopped shoots (94.07%) and whole leaves (93.60%) at 100 kg N/ha/yr found moderate in respect of moth emergence. Emergence was least in respect of 75 kg N/ha/yr x whole leaves (87.47%).

Nitrogen level x Feeding frequency

The interactions of N @ 125 kg/ha/yr x 5, 4 and 3 feeds/day was superior in moth emergence (96.20, 96.07 and 95.67%) over N @ 100 kg/ha/yr x 5 (94.47%), 4 (94.27%) and 3 feeds/day (93.47%). However, it was least with the combination of N @ 75 kg/ha/yr x 3 feeds/day (87.33%) (Table 4.19).

Nitrogen level x Feeding method x Feeding frequency

Rearing of silkworms with whole shoots raised using 125 kg N/ha/yr with a feeding regime of 5 and 4 feeds/day recorded 96.40 per cent of moth emergence together with that of chopped shoots x 5 feeds/day (96.20%), chopped shoots x 4 feeds/ day (96.00%), whole leaves x 5 feeds/day (96.00%), whole shoots x 3 feeds/day (96.00%), whole leaves x 4 feeds/day (95.80%), chopped shoots x 3 feeds/day (95.60%) and whole leaves x 3 feeds/day (95.40%) at same level of N. The combination of N @ 75 kg/ha/yr x whole leaves x 3 feeds/day recorded the lowest rate of moth emergence (87.00%) (Table 4.19).

4.4.3.5 Fecundity

Method of feeding silkworms seldom influenced the fecundity.

Nitrogen level

Fecundity was higher in moths emerging from pupae formed by worms which received mulberry obtained with 125 kg N/ha/yr (558.5 eggs/laying) over 100 (535.9 eggs) and 75 kg N/ha/yr (489.8 eggs).

Feeding frequency

Feeding regimes had significant impact on the fecundity of moths, highest being with 5 (533.8 eggs) and 4 feeds/day (529.9 eggs). It was least with 3 feeds/day (520.5 eggs) (Table 4.19).

Nitrogen level x Feeding method

The batches of silkworms fed whole shoots, chopped shoots and whole leaves raised with the application of N @ 125 kg/ha/yr registered the highest fecundity of 564.4, 558.6 and 552.4 eggs. It was lowest with 75 kg N/ha/yr (495.1, 489.9 and 484.4 eggs, respectively).

Nitrogen level x Feeding frequency

The combination of N @ 125 kg/ha/yr x 5 feeds/day recorded highest fecundity of 564.9 eggs along with 4 (560.6 eggs) and 3 feeds/day (549.9 eggs) at same level of N. The next best combinations were N @ 100 kg/ha/yr x 5 (540.6 eggs), 4 (537.8 eggs) and 3 feeds/day (529.2 eggs). Lowest fecundity was noticed with 75 kg N/ha/yr x 3 feeds/day (482.4 eggs) (Table 4.19).

Feeding method x Feeding frequency

Silkworms fed with whole shoots 5 feeds a day gave rise to moths that resulted in highest fecundity (538.5 eggs) together with whole shoots x 4 feeds/day (536.4 eggs), chopped shoots x 5 feeds/day (533.9 eggs), chopped shoots x 4 feeds/day (531.3 eggs), whole leaves x 5 feeds/day (528.9 eggs), whole shoots x 3 feeds/day (524.9 eggs), whole leaves x 4 feeds/day (522.0 eggs) and chopped shoots x 3 feeds/day (519.4 eggs). It was lowest with whole leaves x 3 feeds/day (517.1 eggs).

Nitrogen level x Feeding method x Feeding frequency

In the second order interaction, moths resulting from worms fed with whole shoots harvested from the plots fertilized with N @ 125 kg/ha/yr at feeding frequency of 5 feeds/day were found superior in fecundity (569.5 eggs) along with whole shoots x 4 feeds/day (568.3 eggs), chopped shoots x 5 feeds/day (565.6 eggs), chopped shoots x 4 feeds/day (562.9 eggs), whole leaves x 5 feeds/day (559.6 eggs), whole shoots x 3 feeds/day (555.4 eggs), whole leaves x 4 feeds day (550.7 eggs), chopped shoots x 3 feeds/day (547.4 eggs) and whole leaves x 3 feeds/day (546.8 eggs) at same level of N. However, in other combinations fecundity varied from 478.1 to 544.4 eggs (Table 4.19 and Fig. 4.6).

4.4.3.6 Hatchability

Non-significant difference existed among methods of feeding with respect to hatchability of eggs.

Nitrogen level

Hatchability was higher in eggs laid by moths resulting from pupae formed from worms fed on mulberry fertilized with N @ 125 kg/ha/yr (95.26%) over 100 (93.75%) and 75 kg/ha/yr (90.24%).

Feeding frequency

Feeding regimes had significant influence on hatchability of eggs, highest being with 5 feeds/day (93.59%) together with 4 feeds/day (93.27%). However hatchability was lower with 3 feeds/day (92.40%) (Table 4.19).

Nitrogen level x Feeding method

Silkworms reared on whole shoots of mulberry raised at 125 kg N/ha/yr recorded higher hatchability of 95.55 per cent, along with chopped shoots (95.27%) and whole leaves (94.96%). Hatchability was lower with 75 kg N/ha/yr x whole leaves (89.43%).

Nitrogen level x Feeding frequency

The combination of N level and feeding regimes produced considerable variations with regard to hatchability. Higher hatching

Table 4.19 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on rate of moth emergence, fecundity and hatchability

Parameters		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
Rate of moth emergence (%)	N_1	88.11 (69.90)	M_1	92.27 (74.36)	F_1	92.16 (74.21)	N_1	87.47 (69.31)	88.87 (70.61)	88.00 (69.79)	N_1	87.33 (69.20)	88.27 (70.04)	88.73 (70.46)	M_1	91.80 (73.80)	92.33 (74.48)	92.67 (74.81)	M_1	87.00 (68.90)	87.40 (69.25)	88.00 (69.77)	93.00 (74.76)	93.80 (75.73)	94.00 (75.95)	95.40 (77.74)	95.80 (78.46)	96.00 (78.72)
	N_2	94.07 (76.08)	M_2	93.22 (75.49)	F_2	92.87 (75.06)	N_2	93.60 (75.48)	94.53 (76.69)	94.07 (76.05)	N_2	93.47 (75.30)	94.27 (76.31)	94.47 (76.62)	M_2	92.53 (74.64)	93.47 (75.79)	93.67 (76.02)	M_2	87.60 (69.44)	89.20 (70.91)	89.80 (71.47)	94.00 (75.90)	94.80 (77.02)	94.80 (77.16)	96.00 (78.58)	96.40 (79.44)	96.40 (79.44)
	N_3	95.98 (78.68)	M_3	92.67 (74.80)	F_3	93.13 (75.39)	N_3	95.73 (78.31)	96.27 (79.16)	95.93 (78.57)	N_3	95.67 (78.13)	96.07 (78.82)	96.20 (79.09)	M_3	92.13 (74.18)	92.80 (74.90)	93.07 (75.33)	M_3	87.40 (69.26)	88.20 (69.96)	88.40 (70.14)	93.40 (75.23)	94.20 (76.17)	94.60 (76.75)	95.60 (78.06)	96.00 (78.55)	96.20 (79.10)
S.Em ±		0.493		0.493		0.493			0.854				0.854				0.854							2.560				
C.D. at 5%		1.398		-		-			2.421				2.421				-							4.190				
Fecundity (eggs/laying)	N_1	489.8	M_1	522.7	F_1	520.5	N_1	484.4	495.1	489.9	N_1	482.4	491.2	495.8	M_1	517.1	522.0	528.9	M_1	478.1	484.7	490.3	526.4	530.5	536.8	546.8	550.7	559.6
	N_2	535.9	M_2	533.2	F2	529.9	N_2	531.2	540.2	536.1	N_2	529.2	537.8	540.6	M_2	524.9	536.4	538.5	M_2	486.5	496.5	502.4	532.7	544.4	543.5	555.4	568.3	569.5
	N_3	558.5	M_3	528.2	F_3	533.8	N_3	552.4	564.4	558.6	N_3	549.9	560.6	564.9	M_3	519.4	531.3	533.9	M_3	482.5	492.5	494.6	528.4	538.4	541.6	547.4	562.9	565.6
S.Em ±		3.897		3.897		3.897			6.750				6.750				6.750							20.25				
C.D. at 5%		11.05		-		11.05			19.14				19.14				19.14							33.15				
Hatchability (%)	N_1	90.24 (71.88)	M_1	92.59 (74.48)	F_1	92.40 (74.25)	N_1	89.43 (71.11)	90.97 (72.58)	90.33 (71.96)	N_1	89.17 (70.83)	90.47 (72.09)	91.10 (72.72)	M_1	92.03 (73.84)	92.58 (74.44)	93.16 (75.15)	M_1	88.50 (70.23)	89.20 (70.86)	90.60 (72.24)	93.00 (74.72)	93.55 (75.31)	93.62 (75.57)	94.60 (76.57)	95.00 (77.16)	95.27 (77.62)
	N_2	93.75 (75.63)	M_2	93.51 (75.54)	F_2	93.27 (75.24)	N_2	93.39 (75.20)	94.02 (76.00)	93.83 (75.68)	N_2	93.16 (74.91)	93.98 (75.90)	94.11 (76.07)	M_2	92.79 (74.69)	93.80 (75.84)	93.95 (76.08)	M_2	90.00 (71.60)	91.40 (73.01)	91.50 (73.13)	93.17 (74.97)	94.40 (76.44)	94.50 (76.57)	95.20 (77.49)	95.60 (78.06)	95.85 (78.54)
	N_3	95.26 (77.61)	M_3	93.15 (75.11)	F_3	93.59 (75.63)	N_3	94.96 (77.12)	95.55 (78.03)	95.27 (77.69)	N_3	94.87 (77.03)	95.35 (77.71)	95.56 (78.10)	M_3	92.37 (74.23)	93.42 (75.43)	93.65 (75.66)	M_3	89.00 (70.65)	90.80 (74.42)	91.20 (72.79)	93.30 (75.03)	94.00 (75.95)	94.20 (76.06)	94.80 (77.02)	95.45 (77.91)	95.56 (78.13)
S.Em ±		0.430		0.430		0.430			0.744				0.744				0.744							2.230				
C.D. at 5%		1.218		-		1.218			2.110				2.110				2.110							3.650				

Figures in the parentheses are angular transformed values

N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

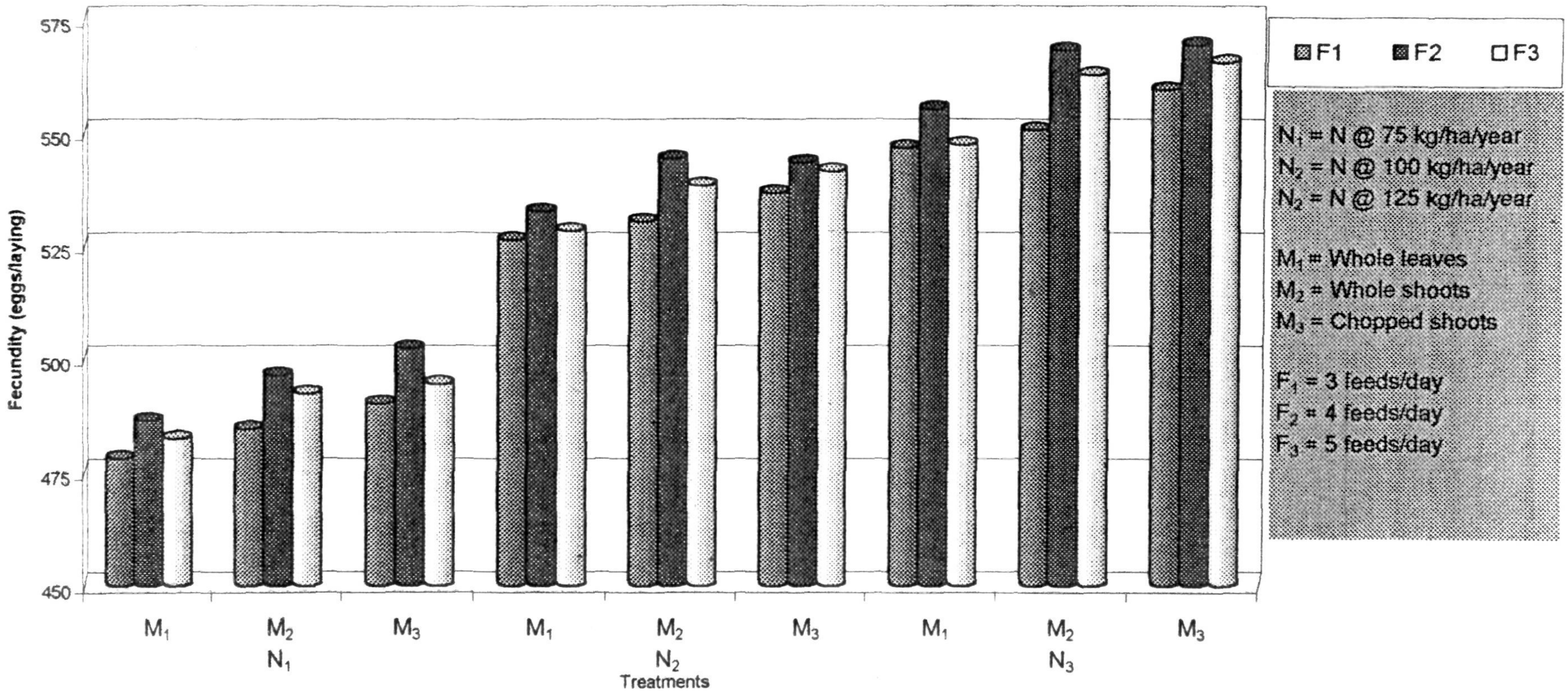

Fig. 4. 6 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on fecundity

was found at 125 kg N/ha/yr in combination with 5 (95.56%), 4 (95.35%) and 3 feeds/day (94.87%). It was lower with 75 kg N/ha/yr x 5, 4 and 3 feeds/day (91.10, 90.47 and 89.17%) (Table 4.19).

Feeding method x Feeding frequency

Method of feeding silkworms in combination with schedule of feeding registered significant influence on hatching of eggs. The combination of whole shoots x 5 feeds/day was better for hatchability (93.95%) along with whole shoots x 4 feeds/day (93.80%), chopped shoots x 5 feeds/day (93.65%), chopped shoots x 4 feeds/day (93.42%), whole leaves x 5 feeds/day (93.16%), whole shoots x 3 feeds/day (92.79%), whole leaves x 4 feeds/day (92.58%) and chopped shoots x 3 feeds/day (92.37%). However, it was lower with whole leaves x 3 feeds/day (92.03%).

Nitrogen level x Feeding method x Feeding frequency

The interaction of N @ 125 kg/ha/yr x whole shoots x 5 feeds/day caused higher hatchability of 95.85 per cent along with whole shoots x 4 feeds/day (95.60%), chopped shoots x 5 feeds/day (95.56%), chopped shoots x 4 feeds/day (95.45%), whole leaves x 5 feeds/day (95.27%), whole shoots x 3 feeds/day (95.20%), whole leaves x 4 feeds/day (95.00%), chopped shoots x 3 feeds/day (94.80%) and whole leaves x 3 feeds/day (94.60%) at same level of N. However, N @ 75 kg/ha/yr x whole leaves x 3 feeds/day was found poorest of all the treatments (88.50 %) (Table 4.19).

4.5 CORRELATION CO-EFFICIENTS BETWEEN FOILAR CONSTITUENTS OF RAINFED MULBERRY AND ECONOMIC PARAMETERS OF SILKWORM

The data on correlation co-efficients (r) between foliar constituents of mulberry raised at varied levels of N with rearing, cocoon and grainage parameters are presented in Table 4.20.

4.5.1 REARING PARAMETERS

Rearing parameters viz., larval weight, larval survival ERR, cocoon yield and silk productivity established significant positive relationship with foliar constituents like moisture, chlorophyll 'a', 'b' and total chlorophyll, total carbohydrates, crude protein, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur except for larval weight with sulphur ; Larval survival and ERR with crude protein, nitrogen and sulphur and cocoon yield and silk productivity with phosphorus, while larval duration established negatively significant relationship with these constituents (Table 4.20 and Fig. 4.7).

4.5.2 COCOON PARAMETERS

The relationship between foliar constituents viz., moisture, chlorophyll 'a', 'b' and total chlorophyll, total carbohydrates, crude protein, nitrogen, potassium calcium, magnesium and sulphur was positively significant with cocoon weight, shell weight, shell ratio, cocoon filament length and fibroin content but that with moisture and shell ratio and potassium with shell weight and shell ratio was non-significant. Further, phosphorus content in leaf did not influence the cocoon parameters. However, the trend was negatively significant with denier and sericin content except that of denier with chlorophyll 'a',

Table 4.20: Correlation co-efficients between foliar constituents of rainfed mulberry raised with varied levels of nitrogen (CAN) and economic parameters of silkworm

Source	Moisture	Chlorophyll			Total carbo-hydrates	Crude protein	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
		a	b	Total								
Rearing parameters												
Larval weight	0.9998*	0. 9590*	0.9883*	0.9743*	0.9977*	0.9532*	0.9538*	0.9698*	0.9994*	0.9902*	0.9618*	0.9473
Larval duration	-0.9992*	-0.9740*	-0.9956*	-0.9859*	-0.9999*	-0.9693*	-0.9698*	-0.9538*	-0.9958*	-0.9967*	-0.9763*	-0.9644*
Larval survival	0.9995*	0.9554*	0.9863*	0.9715*	0.9967*	0.9494	0.9497	0.9727*	0.9997*	0.9885*	0.9584*	0.9433
ERR	0.9994*	0.9551*	0.9862*	0.9712*	0.9967*	0.9491	0.9492	0.9730*	0.9998*	0.9883*	0.9581*	0.9429
Cocoon yield	0.9929*	0.9888*	0.9999*	0.9960*	0.9976*	0.9857*	0.9860*	0.9271	0.9853*	0.9999*	0.9903*	0.9823*
Silk productivity	0.9729*	0.9994*	0.9951*	0.9997*	0.9831*	0.9985*	0.9986*	0.8780	0.9592*	0.9936*	0.9997*	0.9973*
Cocoon parameters												
Cocoon weight	0.9669*	0.9999*	0.9924*	0.9988*	0.9783*	0.9995*	0.9996*	0.8660	0.9519*	0.9906*	0.9999*	0.9988*
Shell weight	0.9556*	0.9996*	0.9864*	0.9959*	0.9689*	0.9999*	0.9999*	0.8447	0.9385	0.9841*	0.9992*	0.9999*
Shell ratio	0.9379	0.9963*	0.9759*	0.9894*	0.9539*	0.9978*	0.9977*	0.8140	0.9181	0.9728*	0.9954*	0.9989*
Filament length	0.9920*	0.9899*	0.9999*	0.9966*	0.9971*	0.9869*	0.9872*	0.9244	0.9840*	0.9999*	0.9913*	0.9836*
Denier	-0.9948*	-0.9314	-0.9719*	-0.9516*	-0.9885*	-0.9240	-0.9248	-0.9875*	-0.9992*	-0.9749*	-0.9352	-0.9165
Fibroin	0.9871*	0.9941*	0.9997*	0.9988*	0.9939*	-0.9918*	0.9920*	0.9110	0.9773*	0.9993*	0.9952*	0.9892*
Sericin	-0.9866*	-0.9946*	-0.9996*	-0.9991*	-0.9934*	0.9923*	-0.9926*	-0.9092	-0.9765*	-0.9991*	-0.9956*	-0.9898*
Grainage parameters												
Rate of pupation	0.9856*	0.9951*	0.9994*	0.9992*	0.9928*	0.9930*	0.9932*	0.9070	0.9754*	0.9988*	0.9961*	0.9905*
Pupal weight	0.9771*	0.9986*	0.9968*	0.9999*	0.9864*	0.9973*	0.9974*	0.8870	0.9644*	0.9956*	0.9990*	0.9957*
Pupal duration	-0.9993*	-0.9538*	-0.9855*	-0.9702*	-0.9963*	-0.9477	-0.9483	-0.9740*	-0.9999*	-0.9876*	-0.9568*	-0.9414
Rate of moth emergence	0.9773*	0.9984*	0.9968*	0.9999*	0.9865*	0.9972*	0.9973*	0.8874	0.9646*	0.9957*	0.9990*	0.9956*
Fecundity	0.9928*	0.9889*	0.9999*	0.9960*	0.9975*	0.9858*	0.9862*	0.9267	0.9851*	0.9999*	0.9904*	0.9825*
Hatchability	0.9886*	0.9931*	0.9999*	0.9984*	0.9948*	0.9906*	0.9909*	0.9146	0.9792*	0.9996*	0.9942*	0.9878*

* Significant at P = 0.05

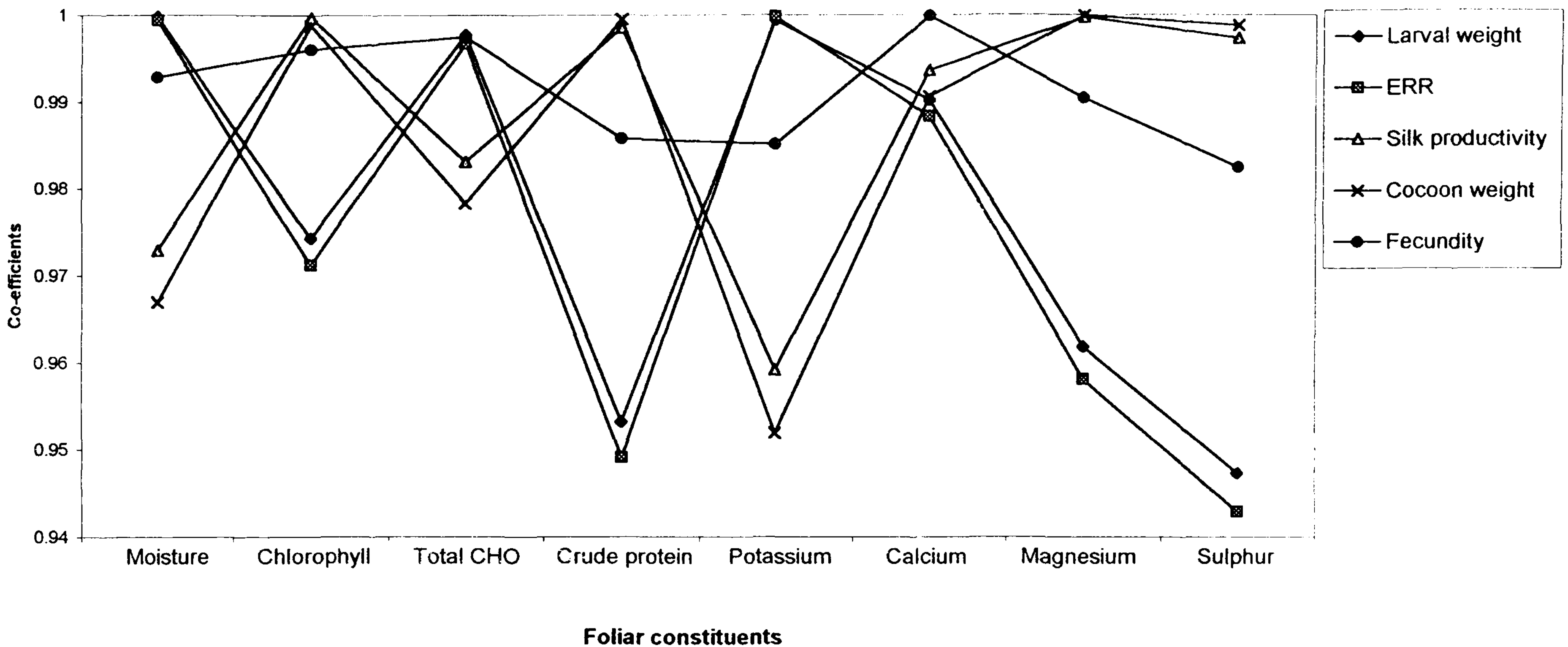

Fig.4. 7 : Correlation co-efficients between foliar constituents of rainfed mulberry raised with different levels of nitrogen (CAN) and economic parameters of silkworm

crude protein, nitrogen, magnesium and sulphur and sericin with phosphorus (Table 4.20 and Fig. 4.7).

4.5.3 GRAINAGE PARAMETERS

The correlation co-efficients between foliar constituents and grainage parameters like rate of pupation, pupal weight, rate of moth emergence, fecundity and hatchability were found positively significant except with phosphorus which was non-significant. However, these foliar constituents except crude protein, nitrogen and sulphur showed negatively significant relation with pupal duration (Table 4.20 and Fig. 4.7).

4.6 ECONOMICS OF RAINFED MULBERRY PRODUCTION PER HECTARE UNDER DIFFERENT LEVELS OF NITROGEN (CAN)

The data on the comparative economics of rainfed mulberry production per hectare under different levels of N (CAN) fertilization are presented in Table 4.21.

4.6.1 Cost of mulberry production

The estimated cost of mulberry production per hectare without inclusion of N fertilizer is presented in Appendix - III. The total cost of mulberry production was highest with N @ 125 kg/ha/yr (Rs.18,077), of which the cost of N accounted for Rs.3,200, followed by 100 kg/ha/yr (Rs.17,437 and Rs.2,560) and was least with 75 kg/ha/yr (Rs.16,797 and Rs.1,920) (Table 4.21)

Table 4.21: Comparative economics of rainfed mulberry production per hectare under different levels of nitrogen (CAN) fertilization

Sl. No.	Treatments	Cost of mulberry production (Rs.)	Leaf yield (kg/ha/ Year)	Gross profit (Rs.)	Net profit (Rs.)	Benefit: Cost ratio
1	N @ 75 kg/ha/year	16,797 (1,920)	12,786	19,179	2,381	0.142 : 1
2	N @ 100 kg/ha/year	17,437 (2,560)	14,234	21,351	3,913	0.224 : 1
3	N @ 125 kg/ha/year	18,077 (3,200)	14,964	22,446	4,368	0.242 : 1

Figures in the parentheses indicate cost of nitrogen (CAN)
Cost of CAN = Rs.6.40 per kg
Cost of leaf = Rs.1.50 per kg

4.6.2 Leaf yield and Cost (gross profit)

The estimated leaf yield was highest with N @ 125 kg/ha/yr (14,964 kg/ha/yr) and its corresponding cost was Rs.22,446 as compared to 100 (14,964 kg and Rs.21,351) and 75 kg/ha/yr (12,786 kg and Rs.19,179).

4.6.3 Net profit

Application of N @ 125 kg/ha/yr contributed for higher net profit of Rs.4,368 when compared to 100 (Rs.3,913) and 75 kg/ha/yr (Rs 2,381) indicating that increased use of N had resulted in getting higher income from mulberry.

4.6.4 Benefit: Cost ratio

The B:C ratio was higher (0.242 : 1) with the use of N @ 125 kg/ha/yr in mulberry production, followed by 100 kg/ha/yr (0.224 :1) and it was least with 75 kg/ha/yr (0.142 :1) (Table - 4.21)

4.7 ECONOMICS OF COCOON PRODUCTION FOR 100 DFLs UNDER DIFFERENT LEVELS OF NITROGEN (CAN), METHODS AND FREQUENCIES OF FEEDING

The comparative economics of silk cocoon production for 100 dfls under different methods and frequencies of feeding mulberry raised at varied levels of N to silkworms are presented in Table 4.22 and 4.23.

4.7.1 Mulberry leaf and Cost

Nitrogen level

The estimated quantity of mulberry leaf required for cocoon production was significantly lower with N @ 75 kg/ha/yr (776 kg) as compared to 100 (824 kg) and 125 kg/ha/yr (843 kg). However, the cost of leaf was found to be non-significant among the levels of N.

Feeding method

Significantly higher quantity of leaf was required for whole shoot feeding method (831 kg), followed by chopped shoots (826 kg) and was lower with whole leaves (785 kg). The corresponding cost requirement for the methods was Rs.1037, 1030 and 980, respectively.

Feeding frequency

Feeding regimes did influence significantly the quantity of mulberry and also cost required for mulberry with lower being for 3 feeds/day (797 kg and Rs.994), followed by (818 kg and Rs.1020) and 5 feeds/day (827kg and Rs.1032) (Table - 4.22).

Nitrogen level x Feeding method

Silkworms fed on whole mulberry leaves raised at 75 kg N/ha/yr recorded lower quantity (752 kg), followed by chopped shoots (782 kg) and whole shoots (793 kg) at same level of N and the trend was similar for 100 (795, 837 and 839 kg) and 125 kg/ha/yr (809, 857 and 862 kg). However the cost of mulberry was lower with N @ 100 kg/ha/yr x whole leaves (Rs.973), N @ 125 kg/ha/yr x whole leaves (Rs.978) and N @ 75 kg/ha/yr x whole leaves (Rs.988), N @ 100 kg/ha/yr x chopped shoots (Rs.1026) and N @ 100 kg/ha/yr x whole shoots (Rs.1028). The cost was higher with N @ 75 kg/ha/yr x whole shoots (Rs.1042).

Nitrogen level x Feeding frequency

Rearing of silkworms at a feeding frequency of 3 feeds/day in combination with N @ 75 kg/ha/yr recorded lowest quantity of mulberry leaf requirement (763 kg) together with that of 4 feeds/day (777 kg). The cost requirement was lower with N @ 100 kg/ha/yr x 3 feeds/day (Rs.985), N @ 125 kg/ha/yr (Rs.995) and N @ 75 kg/ha/yr (Rs.1003) at same feeding frequency. However, the combination of N @ 125 kg/ha/yr x 5 feeds/day registered higher cost involvement (Rs.1037) (Table 4.22).

Feeding method x Feeding frequency

The quantity of mulberry leaf and the corresponding cost requirement for cocoon production for 100 dfls was lowest with whole leaves x 3 feeds/day (747 kg and Rs.932), 4 (793 kg and Rs.989) and 5 feeds/day (816 kg and Rs.1018). The next best combination were chopped shoots x 3 feeds/day (820 kg and Rs.1023) and whole shoots x 3 feeds/day (824 kg and Rs.1028). It was highest with whole shoots x 5 fees/day (836 kg and Rs.1043).

Nitrogen level x Feeding method x Feeding frequency

The second order interaction of N @ 75 kg/ha/yr x whole leaves x 3 feeds/day required the lowest quantity of leaf (735 kg) along with that of N @ 100 kg/ha/yr x whole leaves x 3 feeds/day (742 kg), N @ 75 kg/ha/yr x whole leaves x 4 feeds/day (750 kg), N @ 125 kg/ha/yr x whole leaves x 3 feeds/day (763 kg) and N @ 75 kg/ha/yr x whole leaves x 5 feeds/day (770 kg). However, the requirement of leaf was higher with N @ 125 kg/ha/yr x whole shoots x 5 feeds/day (865 kg). While the cost of leaf was lower with N @ 100 kg/ha/yr x whole leaves x 3 feeds/day (Rs.909), N @ 125 kg/ha/yr x whole leaves x 3 feeds/day (Rs.922), N @ 75 kg/ha/yr x whole leaves x 3 feeds/day (Rs.966), N @ 75 kg/ha/yr x whole leaves x 4 feeds/day (Rs.985) and N @ 125 kg/ha/yr x whole leaves x 4 feeds/day (Rs.986). Whereas, the cost towards leaf was highest with N @ 75 kg/ha/yr x whole shoots x 5 feeds/day (Rs.1054) (Table 4.22).

4.7.2 Labour and Cost

Nitrogen level

The application of different levels of N did not have impact on the labour requirement for silkworm rearing and also towards its cost.

Feeding method

Different methods of feeding silkworm had significant influence on labour requirement and also its corresponding cost. Labour requirement was more with whole leaves (28.49 md and Rs.1424), followed by chopped shoots (24.54 md and Rs.1227) and it was lowest with whole shoots (22.56 md and Rs.1127).

Feeding frequency

Silkworms fed 5 times a day consumed more amount of labour (26.94 md and Rs.1346) as compared to 4 times a day (25.21 md and Rs.1260) and it was less with 3 times a day (23.44 md and Rs.1171) (Table 4.22).

Nitrogen level x Feeding method

Supplying mulberry whole shoots to silkworms raised with 75,100 and 125 kg N/ha/yr demanded less labour (22.50, 22.57 and 22.60 md) and the corresponding cost involved was Rs.1125, 1128 and 1130 and the next best combination was chopped shoots (24.53 md and Rs.1226 ; 24.54 md and Rs.1227 ; 24.56 md and Rs.1228) and the same was more with whole leaves raised at same levles of N (28.53 md and Rs.1426 ; 28.41 md and Rs.1420 ; 28.52 md and Rs.1426, respectively).

Nitrogen level x Feeding frequency

Feeding regimes in combination with N levels had profound influence on labour requirement for silkworm rearing. Silkworms fed 3 times a day with mulberry raised at 100 N kg /ha/yr recorded lower requirement and cost (23.42 md and Rs.1170) and it was 23.45 md and Rs.1172 with 75 and 125 kg N/ha/yr at same feeding regime. Feeding worms 4 times a day at 75 (25.16 md and Rs.1257), 100 (25.20 md and Rs.1259) and 125 kg N/ha/yr (25.27 md and Rs.1263) was next best with moderate labour requirement. However, the requirement of labour was more with 5 feeds/day (26.91 md and Rs.1345 ; 26.95 md and Rs.1347 ; 26.96 md and Rs.1347) at 100, 75 and 125 kg N/ha/yr, respectively. (Table 4.22).

Feeding method x Feeding frequency

Application of mulberry whole shoots 3 times a day to silkworms required less labour and cost (21.05 md and Rs.1052), followed by those with whole shoots x 4 feeds/day (22.50 md and Rs.1125), chopped shoots x 3 feeds/day (22.75 md and Rs.1137) and whole shoots x 5 feeds/day (24.12 md and Rs.1206). Significantly more amount of labour was required to rear worms on whole leaves at 5 times a day (30.54 md and Rs.1527).

Nitrogen level x Feeding method x Feeding frequency

Labour requirement for silkworm rearing varied among the methods and frequencies of feeding mulberry raised at different levels of N fertilization. It was less for whole shoot feeding thrice a day with N @ 75 (21.00 md and Rs.1050), 100 (21.10 md and Rs.1055) and 125 kg/ha/yr (21.05 md and Rs.1052) and 4 feeds/day (22.40 md and Rs.1119 ; 22.50 md and Rs.1125 ; 22.60 md and 1130) with same feeding method. The labour requirement was moderate for chopped shoot feeding and it was more with whole leaf feeding at different levels of N with 5 feeds/day (Table 4.22).

4.7.3 Total cost of production

The cost of silkworm rearing except the cost on mulberry leaf and labour requirement is presented in Appendix - IV.

Nitrogen level

Mulberry receiving N at varied levels did not influenced the cost of silk cocoon production.

Feeding method

The total cost of production was significantly less with whole shoot feeding method (Rs.3810) as compared to chopped shoots (Rs.3902) and it was more with whole leaves (Rs.4051) (Table 4.22).

Feeding frequency

Feeding regimes were found to influence significantly the total cost of production of cocoons, less being with 3 feeds/day (Rs.3811), 4 feeds/day (Rs.3925) and it was more with 5 feeds/day (Rs.4026).

Nitrogen level x Feeding method

Rearing of silkworms with whole shoots in combination with N @ 100, 75 and 125 kg/ha/yr recorded lower cost of production (Rs.3801, 3812 and 3816), with chopped shoots it was Rs.3898, 3900 and 3908 and was higher with whole leaves (Rs.4039, 4060 and 4054), respectively (Table 4.22).

Nitrogen level x Feeding frequency

The combination of N @ 100 kg/ha/yr x 3 feeds/day (Rs.3801), 125 kg/ha/yr (Rs.3813) and 75 kg/ha/yr (Rs.3821) with same feeding frequency recorded least cost of production, the next best being 4 feeds/day (Rs. 3922, 3931 and 3924) and was highest with 5 feeds/day (Rs. 4016, 4035 and 4026, respectively).

Feeding method x Feeding frequency

Offering mulberry whole shoots at a feeding frequency of 3 feeds/day to silkworms recorded least cost of production (Rs.3725), followed by whole shoots x 4 feeds/day (Rs.3810), chopped shoots x 3 feeds/day (Rs.3806) and chopped shoots x 4 feeds/day (Rs.3913). The cost of production was higher with whole leaves x 5 feeds/day (Rs.4196).

Table 4.22 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on cost of production of cocoons for 100 DFLs

Param-eters		N		M		F		N x M				N x F				M x F				N x M x F								
																					N_1			N_2			N_3	
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
	N_1	776 (1019)	M_1	785 (980)	F_1	797 (994)	N_1	752 (988)	793 (1042)	782 (1028)	N_1	763 (1003)	777 (1021)	787 (1034)	M_1	747 (932)	793 (989)	816 (1018)	M_1	735 (966)	750 (985)	770 (1012)	742 (909)	812 (995)	830 (1017)	763 (922)	816 (986)	849 (1026)
ılberry f (kg)	N_2	824 (1009)	M_2	831 (1037)	F_2	818 (1020)	N_2	795 (973)	839 (1028)	837 (1026)	N_2	804 (985)	830 (1017)	837 (1025)	M_2	824 (1028)	833 (1040)	836 (1043)	M_2	780 (1025)	796 (1046)	802 (1054)	836 (1024)	840 (1029)	841 (1030)	856 (1034)	864 (1044)	865 (1045)
	N_3	843 (1018)	M_3	826 (1030)	F_3	827 (1032)	N_3	809 (978)	862 (1041)	857 (1035)	N_3	824 (995)	846 (1022)	858 (1037)	M_3	820 (1023)	827 (1031)	830 (1035)	M_3	775 (1018)	784 (1031)	788 (1036)	834 (1022)	838 (1027)	840 (1029)	852 (1029)	858 (1036)	861 (1040)
		4.345		4.345		4.345			7.526				7.526				7.526							22.58				
Em ±		12.32		12.32		12.32			21.34				21.34				21.34							36.95				
). at 5%		(5.439)		(5.439)		(5.439)			(9.420)				(9.420)				(9.420)							(28.26)				
		(-)		(15.42)		(15.42)			(26.71)				(26.71)				(26.71)							(46.26)				
	N_1	25.19 (1259)	M_1	28.49 (1424)	F_1	23.44 (1171)	N_1	28.53 (1426)	22.50 (1125)	24.53 (1226)	N_1	23.45 (1172)	25.16 (1257)	26.95 (1347)	M_1	26.52 (1325)	28.40 (1420)	30.54 (1527)	M_1	26.55 (1327)	28.40 (1419)	30.65 (1532)	26.40 (1320)	28.37 (1418)	30.45 (1522)	26.60 (1330)	28.44 (1422)	30.52 (1526)
our ındays)	N_2	25.17 (1258)	M_2	22.56 (1127)	F2	25.21 (1260)	N_2	28.41 (1420)	22.57 (1128)	24.54 (1227)	N_2	23.42 (1170)	25.20 (1259)	26.91 (1345)	M_2	21.05 (1052)	22.50 (1125)	24.12 (1206)	M_2	21.00 (1050)	22.40 (1119)	24.10 (1205)	21.10 (1055)	22.50 (1125)	24.12 (1206)	21.05 (1052)	22.60 (1130)	24.15 (1207)
	N_3	25.23 (1261)	M_3	24.54 (1227)	F_3	26.94 (1346)	N_3	28.52 (1426)	22.60 (1130)	24.56 (1228)	N_3	23.45 (1172)	25.27 (1263)	26.96 (1347)	M_3	22.75 (1137)	24.73 (1236)	26.15 (1307)	M_3	22.80 (1140)	24.68 (1234)	26.10 (1305)	22.75 (1137)	24.72 (1236)	26.15 (1307)	22.70 (1135)	24.78 (1239)	26.20 (1310)
		0.084		0.084		0.084			0.146				0.146				0.146							0.440				
m ±		-		0.238		0.238			0.413				0.413				0.413							0.710				
). at 5%		(4.205)		(4.205)		(4.205)			(7.284)				(7.284)				(7.284)							(21.85)				
		(-)		(11.92)		(11.92)			(20.65)				(20.65)				(20.65)							(35.77)				
	N_1	3924	M_1	4051	F_1	3811	N_1	4060	3812	3900	N_1	3821	3924	4026	M_1	3903	4054	4196	M_1	3939	4050	4189	3874	4058	4184	3897	4053	4214
al	N_2	3913	M_2	3810	F_2	3925	N_2	4039	3801	3898	N_2	3801	3922	4016	M_2	3725	3810	3894	M_2	3720	3811	3904	3724	3799	3881	3732	3819	3897
.)	N_3	3926	M_3	3902	F_3	4026	N_3	4054	3816	3908	N_3	3813	3931	4035	M_3	3806	3913	3987	M_3	3803	3910	3986	3804	3908	3981	3809	3920	3995
m ±		9.176		9.176		9.176			15.89				15.89				15.89							47.68				
. at 5%		-		26.01		26.01			45.06				45.06				45.06							78.04				

Figures in the parentheses are value in rupees, Cost of labour = Rs. 50 per manday, Cost of mulberry in N_1 = Rs. 1.313 per kg; N_2 = Rs. 1.225 per kg; N_3 = Rs. 1.208 per kg

N= Nitrogen level : N_1= 75 kg/ha/year, N_2= 100 kg/ha/year, N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves, M_2 = Whole Shoots, M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day, F_2 = 4 feeds/day, F_3 = 5 feeds/day

Nitrogen level x Feeding method x Feeding frequency

The second order interaction also showed significant difference with regard to total cost of production, lowest being with N @ 75 kg/ha/yr x whole shoots x 3 feeds/day (Rs.3720), N @ 100 kg/ha/yr (Rs.3724) and N @ 125 kg/ha/yr (Rs.3732) with same method and frequency of feeding. However, the cost of production was higher with N @ 125 kg/ha/yr x whole leaves x 5 feeds/day (Rs.4214) (Table 4.22).

4.7.4 Cocoon yield and Cost (gross profit)

Nitrogen level

Silkworms fed with mulberry obtained by applying N @ 125 kg/ha/yr recorded higher cocoon yield and cost (74.79 kg/100 dfls and Rs.13,087) when compared to N @ 100 (67.25 kg and Rs.11,768) and 75 kg/ha/yr (51.93 kg and Rs.9,087) with distinct differences among them.

Feeding method

The batch of silkworms fed mulberry through whole shoots registered significantly higher cocoon yield (66.75 kg and Rs.11,680), followed by chopped shoots (64.89 kg and Rs.11,355) and was lower with whole leaves (62.33 kg and Rs.10,907).

Feeding frequency

Schedule of feeding silkworms did influence the cocoon yield and cost of cocoons. Significantly higher cocoon yield was obtained with worms fed 5 times a day (66.59 kg and Rs.11,653) when compared to 4 feeds/day (65.32 kg and Rs.11,431) and the yield was lower with 3 feeds/day (62.05 kg and Rs.10,858) (Table 4.23).

Nitrogen level x Feeding method

The combination of N @ 125 kg/ha/yr x whole shoots recorded higher cocoon yield and cost of cocoons (76.21 kg and Rs.13,337), followed by chopped shoots (75.11 kg and Rs.13,143) and whole leaves (73.04 kg and Rs.12,782.0). The yield and cocoon cost were lower with N @ 75 kg/ha/yr (54.95 kg and Rs.9,616 ; 52.00 kg and Rs.9,100 ; 48.83 kg and Rs.8,544, respectively).

Nitrogen level x Feeding frequency

Silkworms receiving mulberry raised with 125 kg N/ha/yr x 5 times a day were found superior in yielding more cocoon weight and cost (76.39 kg and Rs.13,367) along with that of 4 (75.12 kg and Rs.13,146) and 3 times a day (72.85 kg and Rs.12,749) at same level of N. Next in the order was N application @ 100 kg/ha/yr (68.57 kg and Rs.12,000 ; 67.80 kg and Rs.11,865 ; 65.37 kg and Rs.11,439). However, the combination of 75 kg N/ha/yr x 3 feeds/day resulted in less quantity of cocoons and lowest cocoon cost (47.93 kg and Rs.8,387) (Table 4.23).

Feeding method x Feeding frequency

The interaction of method and frequency of feeding was significant with respect to cocoon yield, higher being with whole shoots x 5 feeds/day (68.24 kg and Rs.11,942), followed by whole shoots x 4 feeds/day (67.91 kg and Rs.11,884), chopped shoots x 5 feeds/day (66.95 kg and Rs.11,715) and chopped shoots x 4 feeds/day (65.76 kg and Rs.11,508). It was lower with whole leaves x 3 feeds/day (60.11 kg and Rs.10,518).

Nitrogen level x Feeding method x Feeding frequency

The combination of 125 kg N/ha/yr with whole shoots x 5 feeds/day (77.62 kg and Rs.13,583), whole shoots x 4 feeds/day (76.82 kg and Rs.13,443), chopped shoots x 5 feeds/day (76.68 kg and Rs.13,419) chopped shoots x 4 feeds/day (75.58 kg and Rs.13,226) and whole leaves x 5 feeds/day (74.86 kg and Rs.13,100) registered higher cocoon yield. However, it was lower with N @ 75 kg/ha/yr x whole leaves x 3 feeds/day (45.42 kg and Rs.7,948) (Table 4.23).

4.7.5 Net profit

Nitrogen level

Net profit per 100 dfls did differ significantly among the levels of N applied to mulberry, more being with 125 kg N/ha/yr (Rs.9,162) as compared to 100 (Rs.7,855) and 75 kg/ha/yr (Rs.5,126).

Feeding method

Silkworms reared on whole shoots yielded higher net profit (Rs.7,833) and it was moderate with chopped shoots (Rs.7,452). However, the net realisation was lower with whole leaves (Rs.6,857).

Feeding frequency

Silkworms fed mulberry 5 times a day yielded higher net profit (Rs.7,629) over 4 (Rs.7,505) and 3 times a day (Rs.7,009) (Table 4.23).

Nitrogen level x Feeding method

Rearing of silkworms by supplying mulberry whole shoots, chopped shoots and whole leaves raised with 125 kg N/ha/yr recorded higher net benefit of Rs.9,520, 9,234 and 8,732, the next best being 100 kg N/ha/yr (Rs.8,286, 7,923 and 7,355) and net profit was lower with 75 kg N/ha/yr (Rs. 5,693, 5,200 and 4,484, respectively).

Nitrogen level x Feeding frequency

Net profit increased with increase in the application of N to mulberry and also with increased frequency of feeding, highest being with 125 kg N/ha/yr x 5 feeds/day (Rs.9,337), followed by 4 (Rs.9,214) and 3 feeds/day (Rs.8,936) at same level of N. However, it was lowest with 75 kg N/ha/yr x whole leaves (Rs.4,454).

Feeding method x Feeding frequency

Rearing of silkworms through different methods at varied frequencies also influenced the net profit per 100 dfls. The combination of whole shoots x 4 feeds/day (Rs.8,074), whole shoots x 5feeds/day (Rs.8,047), chopped shoots x 5 feeds/day (Rs.7,727), chopped shoots x 4 feeds/day (Rs.7,595), whole shoots x 3 feeds/day (Rs.7,378) and whole leaves x 5 feeds/day (Rs.7,112) recorded higher profit. However, the net profit was least with whole leaves x 3 feeds/day (Rs.6,615) (Table 4.23).

Nitrogen level x Feeding method x Feeding frequency

The interaction of 125 kg N/ha/yr x whole shoots x 5 feeds/day recorded more net profit (Rs.9,685) together with whole shoots x

4 feeds/day (Rs.9,624), chopped shoots x 5 feeds/day (Rs.9,423). However, it was less with N @ 75 kg/ha/yr x whole leaves x 3 feeds/day (Rs.4,009) (Table 4.23).

4.7.6 B:C ratio

Nitrogen level

B:C ratio was significantly more with 125 kg N/ha/yr (2.338:1), followed by 100 (2.011:1) and 75 kg/ha/yr (1.318:1) with distinct differences among them.

Feeding method

Silkworms when offered mulberry whole shoots recorded more B:C ratio (2.065:1) over those on chopped shoots (1.908:1) and it was least with worms receiving whole leaves (1.694:1).

Feeding frequency

Feeding regimes did significantly influenced the B:C ratio, more being with 4 feeds/day (1.916 :1), followed by 5 feeds/day (1.900 :1) and it was lower with 3 feeds/day (1.852:1) with statistical differences among them (Table 4.23).

Nitrogen level x Feeding method

Significantly more B:C ratio was encountered with the combination of 125 kg N/ha/yr x whole shoots (2.495:1) and chopped shoots (2.362:1). However, it was less with 75 kg N/ha/yr x whole leaves (1.103:1).

Table 4.23 : Influence of feeding silkworm through different methods and frequencies with rainfed mulberry raised at varied levels of nitrogen (CAN) on returns from cocoons for 100 DFLs

Param-eters		N		M		F		N x M				N x F				M x F				N x M x F								
																				N_1			N_2			N_3		
								M_1	M_2	M_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
Cocoon Yield (kg)	N_1	51.93 (9087)	M_1	62.33 (10907)	F_1	62.05 (10858)	N_1	48.83 (8544)	54.95 (9616)	52.00 (9100)	N_1	47.93 (8387)	53.04 (9282)	54.81 (9592)	M_1	60.11 (10518)	62.29 (10900)	64.59 (11302)	M_1	45.42 (7948)	48.78 (8536)	52.28 (9149)	63.60 (11130)	65.12 (11396)	66.62 (11658)	71.30 (12477)	72.96 (12768)	74.86 (13100)
	N_2	67.25 (11768)	M_2	66.75 (11680)	F_2	65.32 (11431)	N_2	65.11 (11394)	69.07 (12087)	67.55 (11821)	N_2	65.37 (11439)	67.80 (11865)	68.57 (12000)	M_2	64.09 (11215)	67.91 (11884)	68.24 (11942)	M_2	51.06 (8935)	56.74 (9929)	57.06 (9985)	67.00 (11725)	70.18 (12281)	70.04 (12257)	74.20 (12985)	76.82 (13443)	77.62 (13583)
	N_3	74.79 (13087)	M_3	64.89 (11355)	F_3	66.59 (11653)	N_3	73.04 (12782)	76.21 (13337)	75.11 (13143)	N_3	72.85 (12749)	75.12 (13146)	76.39 (13367)	M_3	61.95 (10841)	65.76 (11508)	66.95 (11715)	M_3	47.30 (8277)	53.60 (9380)	55.10 (9642)	65.50 (11462)	68.10 (11917)	69.06 (12085)	73.06 (12785)	75.58 (13226)	76.68 (13419)
S.Em ± C.D. at 5%		0.187 0.530 (32.68) (92.66)		0.187 0.530 (32.68) (92.66)		0.187 0.530 (32.68) (92.66)			0.324 0.917 (56.61) (160.5)				0.324 0.917 (56.61) (160.5)				0.324 0.917 (56.61) (160.5)							0.970 1.590 (170.0) (278.0)				
Net profit (Rs.)	N_1	5126	M_1	6857	F_1	7009	N_1	4484	5693	5200	N_1	4454	5358	5565	M_1	6615	6845	7112	M_1	4009	4485	4959	7255	7337	7473	8580	8714	8903
	N_2	7855	M_2	7833	F2	7505	N_2	7355	8286	7923	N_2	7637	7942	7984	M_2	7378	8074	8047	M_2	4881	6118	6081	8000	8482	8375	9252	9624	9685
	N_3	9162	M_3	7452	F_3	7629	N_3	8732	9520	9234	N_3	8936	9214	9337	M_3	7035	7595	7727	M_3	4473	5470	5656	7657	8009	8103	8975	9305	9423
S.Em ± C.D. at 5%		34.38 97.46		34.38 97.46		34.38 97.46			59.54 168.8				59.54 168.8				59.54 168.8							178.6 292.4				
Benefit : Cost ratio	N_1	1.318:1	M_1	1.694:1	F_1	1.852:1	N_1	1.103:1	1.521:1	1.330:1	N_1	1.198:1	1.370:1	1.386:1	M_1	1.697:1	1.688:1	1.697:1	M_1	1.017:1	1.107:1	1.184:1	1.872:1	1.808:1	1.786:1	2.202:1	2.150:1	2.121:1
	N_2	2.011:1	M_2	2.065:1	F_2	1.916:1	N_2	1.822:1	2.179:1	2.032:1	N_2	2.011:1	2.030:1	1.993:1	M_2	2.010:1	2.119:1	2.067:1	M_2	1.402:1	1.605:1	1.557:1	2.148:1	2.232:1	2.158:1	2.479:1	2.520:1	2.485:1
	N_3	2.338:1	M_3	1.908:1	F_3	1.900:1	N_3	2.158:1	2.495:1	2.362:1	N_3	2.346:1	2.348:1	2.321:1	M_3	1.848:1	1.941:1	1.936:1	M_3	1.176:1	1.399:1	1.416:1	2.013:1	2.050:1	2.035:1	2.356:1	2.373:1	2.359:1
S.Em ± C.D. at 5%		0.004 0.012		0.004 0.012		0.004 0.012			0.007 0.021				0.007 0.021				0.007 0.021							0.020 0.046				

Figures in the parentheses are values in rupees, Cost of cocoons = Rs. 175 per kg.

N= Nitrogen level : N_1= 75 kg/ha/year
N_2= 100 kg/ha/year
N_3 = 125 kg/ha/year

M= Feeding method : M_1 = Whole leaves
M_2 = Whole Shoots
M_3= Chopped shoots

F= Feeding frequency : F_1 = 3 feeds/day
F_2 = 4 feeds/day
F_3 = 5 feeds/day

Nitrogen level x Feeding frequency

The interactions of 125 kg N/ha/yr with 4, 3 and 5 feeds/day caused for more B:C ratio of 2.348:1, 2.346:1 and 2.321:1, it was moderate with 100 kg N/ha/yr (2.030:1, 2.011:1 and 1.993:1), while application of N @ 75 kg/ha/yr recorded less B:C ratio of 1.386:1, 1.370:1 and 1.198 with 5, 4 and 3 feeds/day, respectively (Table 4.23).

Feeding method x Feeding frequency

Silkworms fed mulberry whole shoots 4 feeds/day registered more B:C ratio of 2.119:1, followed by 5 (2.067:1) and 3 feeds/day (2.010 :1), it was moderate with chopped shoots (1.941:1, 1.936:1 and 1.848:1, respectively). However, B:C ratio was least with whole leaves x 4 feeds/day (1.688:1).

Nitrogen level x Feeding method x Feeding frequency

B:C ratio was highest with 125 kg N/ha/yr x whole shoots x 4 feeds/day (2.520:1) together with whole shoots x 5 feeds/day (2.485:1) and whole shoots x 3 feeds/day (2.479:1) at same level of N. It was lowest with 75 kg N/ha/yr x whole leaves x 3 feeds/day (1.017:1).

DISCUSSION

V. DISCUSSION

The results of the investigations on the "Effect of nitrogen levels on yield and quality of rainfed mulberry in relation to performance of silkworm with different methods and regimes of feeding" are discussed in the light of earlier work under appropriate headings.

5.1 INFLUENCE OF NITROGENOUS SOURCES ON THE PERFORMANCE OF RAINFED MULBERRY

5.1.1 Leaf yield

The mulberry leaf yield was significantly influenced by nitrogen fertilizer sources. The crop that received N through CAN recorded higher leaf yield (2.407 kg/10 plants and 14,440 kg/ha/hr) over other sources tried and it was least in control (1.512 and 9,072 kg). These results are in accordance with the previous observations (Murthy, 1953 ; Anon., 1986a ; Shankar, 1990 ; Teotia *et al.*, 1992 ; Manjula and Shankar, 1995 ; Subbarayappa *et al.*, 1995), which showed significant improvement in leaf yield due to the application of CAN, followed by urea in irrigated mulberry. Manchashetty (1979) found that the relative efficacy of nitrogenous fertilizer sources was in the order of urea>CAN>ammonium nitrate>ammonium sulphate. Mulberry crop raised through urea super granules along with phosphorus and potassium gave higher leaf yield over CAN and urea (Rajanna *et al.*, 1988 ; Rajanna and Dandin, 1994) under rainfed and irrigated conditions. Sreenivasa Shetty *et al.* (1990) recorded higher leaf yield (15-18%) with the application of NPK complex fertilizer (15:15:15) as basal dose, followed by ammonium chloride - CAN or urea or ammonium sulphate as top dressing. Takagishi (1967) obtained higher leaf yield with ammonium sulphate/chloride, while Subbaswamy *et al.* (1999b) with ammonium sulphate under irrigated conditions. On the contrary, Kasiviswanathan and Iyengar (1968) obtained non-significant in leaf yield due to different sources of nitrogenous fertilizers. The superiority of CAN may be attributed to the fact that, it supplies N both in ammonical and nitrate forms which is beneficial for the differential uptake of N by mulberry. More so the addition of calcium through CAN to red alfisol, characterised by lower calcium, may prove advantageous to crop.

5.1.2 Leaf Moisture

Leaf moisture content was significantly higher in respect of urea (73.82%), followed by CAN (72.41%), ammonium sulphate (71.92%) and ammonium chloride (71.53%) and lower in respect of control (69.03%). The increase in leaf moisture content may be due to the enhancement in hydrogen ion concentration of plant sap due to accumulation of chlorides and less moisture loss by evapo-transpiration (Eaton, 1942). Similar trend was also recorded in irrigated M_5 (Subbarayappa, 1988) and S_{54} (Shankar, 1990) mulberry varieties. However, Manjula (1993) obtained non-significant effect of using different N sources.

5.1.3 Chlorophyll

Nitrogen sources significantly influenced the chlorophyll content of mulberry leaf. Chlorophyll 'a', 'b' and total chlorophyll were highest in respect of CAN (1.726, 0.958 and 2.684 mg/g) and urea (1.691, 0.931 and 2.622 mg/g). Leaf from control recorded lowest chlorophyll (1.335, 0.610 and 1.945 mg/g). These observations are in agreement with the findings of Shankar (1990) and Manjula (1993) as per whom the total chlorophyll content was enhanced by the application of CAN, followed by urea-gypsum.

5.1.4 Total Carbohydrates

Total carbohydrate content was influenced by nitrogenous fertilizer sources. It was highest with CAN (19.89%) and urea (18.23%) and lowest in control (14.29%). Paucity of information on this aspect needs further confirmation under different agro-climatic conditions in order to emphasize the role of nitrogenous sources in governing the total carbohydrate content of mulberry leaf.

5.1.5 Crude protein and Nitrogen

Crude protein and nitrogen contents were highest in leaf corresponding to CAN (20.38 and 3.261%) and ammonium chloride (20.12 and 3.219%) compared to the least in control (12.65 and 2.024%). These observations are comparable with those of Shankar (1990), Sreenivasa Shetty (1988) and Manjula (1993). However, the present results are not in conformity with those of Subbarayappa *et al.* (1995) and Subbaswamy *et al.* (1999b) who obtained higher crude protein and nitrogen with ammonium sulphate under irrigated conditions.

5.1.6 Phosphorus

Phosphorus content of leaf was greatly influenced by different fertilizer sources of N. Significantly higher P content was recorded in leaf corresponding to CAN (0.594%) and urea (0.576%). Lower content of P was noticed in control (0.410%). These results are on parity with the observations of Shankar and Shivashankar (1993) and Subbarayappa *et al.* (1995). However, Manjula (1993) recorded higher leaf P content with urea-rock phosphate.

5.1.7 Potassium

Mulberry leaf raised using CAN and urea registered the highest potassium (2.193% ; 2.162%), while it was lowest in control (1.943%). The increase in K content of leaf may be due to better growth and development of the plant on account of enhanced nutrients in soil. The results corroborate the earlier findings (Sreenivasa Shetty, 1988 ; Subbarayappa *et al.*, 1995 ; Manjula, 1993) as per which similar uptake pattern of K was vivid. Shankar and Shivashankar (1993) obtained non-significant variation in K content with the application of different forms of N under irrigated conditions.

5.1.8 Calcium

Calcium content was highest in respect of CAN (3.028%) and urea (2.997%). However, it was lowest in control (1.582%). Higher content of calcium in leaf in respect of CAN is attributable to the fact that CAN serves as a source of calcium in addition to N. Subbarayappa *et al.* (1995), Shankar and Shivashankar (1993) and Manjula (1993) also postulated similar hypothesis.

5.1.9 Magnesium

Magnesium content was highest with leaf corresponding to CAN (0.706%) and urea (0.663%) and lowest in control (0.513%). Shankar and Shivashankar (1993) too obtained similar results. Manjula (1993) and Subbarayappa *et al.* (1995) noticed non-significant results with nitrogenous sources in irrigated mulberry.

5.1.10 Sulphur

Variation in sulphur content of leaf was observed under different fertilizer N sources, highest one corresponding to CAN (0.358%) and ammonium chloride (0.313%). However, sulphur content was lowest in control (0.191%). These results are in complete conformity with the observations of Shankar and Shivashankar (1993), but not with the results of Manjula (1993) who obtained non-significant observations with regard to sulphur content.

5.2 INFLUENCE OF NITROGENOUS SOURCES ON THE PERFORMANCE OF SILKWORM

5.2.1 Mature larval weight

Silkworms fed with mulberry obtained by applying different sources of nitrogenous fertilizers were greatly influenced in respect of mature larval weight. Significantly highest mature larval weight resulted in respect of CAN (41.52 g/10 larvae) and urea (40.97g). However, lower larval weight was recorded in control (26.38g). The increased larval weight may be due to the fact that the sources have greatly influenced the uptake of macro and secondary nutrients which inturn increased the leaf quality. Shankar (1990), Sreenivasa Shetty (1988) and Manjula (1993) reported that N fertilization and source of N had significant role in enhancing the growth and development of late-age silkworms resulting in higher larval weight.

5.2.2 Total larval duration

Nitrogen sources did influence the total larval duration with shortest being on leaf raised with CAN (26.40 days), urea (27.00 days), ammonium chloride (27.25 days) and ammonium sulphate (27.50

days). Whereas, larval duration was longer in respect of control (30.50 days). The shorter larval duration corresponding to all the N sources may be attributed to the fact that, these leaves might have fulfilled the nutritional requirements of silkworms both qualitatively and quantitatively thereby contributing for reduction of larval duration compared to control.

5.2.3 Larval survival and ERR

Marked differences existed among N sources in respect of larval survival and ERR, highest being with CAN (94.60 and 91.40%) and urea (93.40 and 90.40%). The same were lowest in control (79.00 and 70.40%). The worms might have got proper nourishment with leaves raised using CAN and urea, thereby enhancing the larval survival and as a result the ERR had improved. These results are in conformity with those of Sreenivasa Shetty (1988) and Manjula (1993).

5.2.4 Cocoon yield and Silk productivity

Cocoon yield and silk productivity also registered significant effects due to N sources applied to mulberry. Yield and productivity were highest on leaf corresponding to CAN (36.75 kg/box of 50 dfls and 5.298 cg/day) and urea (35.62 kg and 5.041 cg). However, it was lowest in control (17.07 kg and 2.062 cg). Higher cocoon yield might be due to increased ERR with CAN and urea. Since, silk productivity is the unit weight of cocoon shell per day of fifth instar, its improvement is attributed to the fact that, feeding worms with leaves raised by applying CAN and urea enhanced the shell weight and shortened the duration of fifth instar inturn contributes for higher silk productivity. These results are in accordance with those of Sreenivasa Shetty (1988) and Shankar and Shivashankar (1993). But, Subbaswamy *et al.* (1999b) obtained higher cocoon yield with ammonium sulphate (58.2 kg/100 dfls) in silkworm hybrid, $PMxNB_4D_2$.

5.2.5 Cocoon weight, Shell weight and Shell ratio

When silkworms were fed with leaves obtained by the application of different sources of nitrogenous fertilizers recorded significant influence in cocoon weight, shell weight and shell ratio. Weights of 10 each of cocoons and shells and shell ratio were higher with CAN (21.31g, 4.450g and 20.88%) and urea (21.04g, 4.285g and 20.37%) and least in control (14.85g, 2.052g and 13.82%), respectively. These results are in agreement with the observations of Sreenivasa Shetty (1988), Shankar (1990), Subbarayappa *et al.* (1992) and Manjula (1993) as per whom different sources of N had significantly influenced the cocoon parameters of silkworm.

5.2.6 Single cocoon Filament length and Denier

Significant influence was exerted on single cocoon filament length, whereas denier was not influenced by the sources of N. Longest filament was recorded with mulberry leaf raised using all the fertilizer sources of N, more being with CAN (1144m) and less with ammonium sulphate (1023m). Significantly shorter filament was obtained in control (692m). The denier varied from 2.46 (CAN) to 2.55 (control). Significant improvement in filament length could be attributed to improvement in shell ratio with the application of the sources of N fertilizers. These results fall in line with the observations of Sreenivasa Shetty (1988), Subbarayappa *et al.* (1992), Shankar and Shivashankar (1994) and Manjula (1993).

5.2.7 Fibroin and Sericin

Silkworms fed with leaves obtained by the application of different sources of N were significantly influenced in fibroin and sericin secretion, the superiority being with CAN (78.14 and 20.83%) and urea (77.42 and 21.52%). Whereas control witnessed the lowest fibroin (72.82%) and highest sericin (26.12%) contents. The results indicated that N sources other than CAN had a depressive effect on fibroin secretion. Sericin, an outer layer on fibroin is a gummy substance and its content was found to get reduced advantageously with CAN, whereas other forms of N had contributed for higher or equal amount of sericin. Reduction in sericin content in view of higher fibroin caused by CAN could be regarded as a step in bringing down the industrial pollution. Shankar and Shivashankar (1994) too obtained similar results with N sources under irrigated conditions.

5.2.8 Rate of pupation and Pupal weight

Rate of pupation was highest with CAN (96.44%) and ammonium chloride (95.32%). However, least was with control (80.40%). While different sources of N did not influence the weight of pupae, but weight was significantly lowest with control (12.72 g/10 pupae). Similar trend was observed by Shankar (1990), Subbarayappa *et al.* (1992) and Manjula (1993) with regard to pupal weight, who recorded 1.290, 1.292 and 1.390 g, respectively with CAN fertilizer.

5.2.9 Pupal duration and Rate of moth emergence

The plots which received CAN registered significantly least pupal duration of 11.50 days along with ammonium chloride (12.00 days) and urea (12.50 days), while it was longest in control (13.75 days). Similarly, the rate of moth emergence was higher with CAN (96.48%)

and ammonium chloride (95.60%). However, lower percentage of moth emergence (81.12) was noticed with control. The superiority of CAN was evidenced in pupal duration and rate of moth emergence, as the leaves of these plots were nutritionally richer over other sources.

5.2.10 Fecundity and Hatchability

Significantly higher fecundity was encountered in respect of worms fed with mulberry leaf obtained through CAN (546.4 eggs/laying) and urea (533.5 eggs). However, lower fecundity was associated with control (423.5 eggs). Whereas, hatchability had not varied due to N sources but was significantly higher over control which recorded 80.13 per cent. These results are in close conformity with those of Shankar *et al.* (1999) who opined that higher fecundity with CAN was also due to higher pupal weight in CAN treated plots, since higher pupal weight results in higher fecundity with enhanced egg hatching percentage. Futher, the improvement in grainage parameters could be due to the fact that, these sources provide elements like calcium other than N which may be needed for the synthesis of sulphur containing amino acids like cystine and methionine which may be essential for synthesis of chorion and other proteins necessary for embryo and egg shell development. Calcium may help in strengthening the egg shell. However, concrete conclusion cannot be drawn in this regard due to the non-availability of sufficient literature.

It is clear from the present study that CAN significantly improved the yield and quality of rainfed M_5 mulberry leaf and inturn the rearing, cocoon and grainage traits of NB_4D_2 breed of silkworm.

5.3 EFFECT OF NITROGEN (CAN) LEVELS ON THE PERFORMANCE OF RAINFED MULBERRY

5.3.1 Leaf yield

Increase in levels of N application increased the leaf yield. Higher leaf yield (2.494 ± 0.154 kg/10 plants and 14,964 ± 921.0 kg/ha/yr) was observed in the treatment which received 125 kg/ha/yr over 100 kg/ha/yr (2.372 ± 0.148 kg and 14,234 ± 886.7 kg). However, lowest yield was recorded at 75 kg/ha/yr (2.131 ± 0.054 kg and 12,786 ± 322.3 kg). The findings are in conformity with the previous findings (Kasiviswanathan and Iyengar, 1965, 1969 ; Anon., 1967 ; Rajanna *et al.*, 1988 and Das *et al.*, 1993) who obtained higher yield of mulberry with increased level of N fertilization under rainfed condition. Further, it was opined that the response to N increased with moisture availability. However, Patra and Shankar (1998) could not obtain differences in yield with 100 and 150 kg N/ha/yr in rainfed mulberry which might be due to the insufficient soil moisture content to utilize the available N as evidenced by significant increase in their dry weight (81.01 g /plant) due to application of higher level of N when compared to control (74.79g).

5.3.2 Leaf Moisture

Leaf moisture content varied among different levels of N, highest being with 125 kg/ha/yr (72.08 ± 0.400%) as compared to 100 (70.72 ± 1.196%) and 75 kg/ha/yr (68.95 ±1.099%). Similar observations were also made by Ushioda (1954) Das *et al.* (1993). While, Pain (1965) and Rajanna *et al.* (1988) found that different levels of N had no influence on leaf moisture. It is very well established that, moisture plays a significant role in the development of silkworms. In general, leaves with moderate moisture level would be ideal for a favourable and healthy growth of silkworms (Shankar, 1990).

5.3.3 Chlorophyll

Chlorophyll content of mulberry leaf varied with different levels of N applied to mulberry, highest chlorophyll 'a' (1.748 ± 0.029 mg/g), 'b' (0.982 ± 0.012 mg/g) and total chlorophyll (2.730 ± 0.041 mg/g) being with 125 kg N/ha/yr over 100 and 75 kg/ha/yr. This increase in chlorophyll inturn has beneficial effect in improving the nutrient value of leaf by enhancing all the biological activities in leaf and thus the feeding value gets improved. However, Fotedar *et al.* (1988) reported that increase in N levels from 0 to 400 kg/ha/yr did not influence the total chlorophyll content significantly under irrigated condition.

5.3.4 Total Carbohydrates

The total carbohydrate content in leaf increased with increased levels of N. It was 21.33 ± 0.478, 19.96 ± 0.597 and 17.83 ± 0.902 per cent with 125, 100 and 75 kg N/ha/yr. In the absence of documented literature on this aspect, this may have to be further tested at different agro-climatic conditions to confirm the influence of N levels on carbohydrate content of leaf under rainfed condition.

5.3.5 Crude protein and Nitrogen

The plots that received N @ 125 kg/ha/yr recorded higher crude protein (21.26 ± 0.345%) and nitrogen (3.403 ± 0.055%). While N @ 75 kg/ha/yr supported for least crude protein and nitrogen contents of 17.39 ± 0.453 and 2.783 ± 0.073 per cent and in control (100 kg N/ha/yr) it was 20.60 ± 0.951 and 3.296 ± 0.153 per cent. The increased crude protein may be attributed to the fact that N is an integral component of protein molecules. The results are in conformity with the findings of Pain (1965), Sengupta *et al.* (1972), Ray *et al.* (1973) and Basavanna *et al.* (1974 and 1976). While Katak *et al.* (1979) found non-significant effect of varied levels of N on crude protein content of mulberry leaves.

5.3.6 Phosphorus and Potassium

Phosphorus and potassium contents in leaf differed with different levels of N and the contents were higher with 125 kg/ha/yr (0.624 ± 0.018 and 2.314 ± 0.040%) over 100 (0.590 ± 0.025 and 2.213 ± 0.028 %) and 75 kg/ha/yr (0.573 ± 0.020 and 2.104 ± 0.025%). The phosphorus content is in conformity with the findings of Westfall *et al.* (1973) who reported that increase in 'N' application increased the 'P' uptake due to increased root growth and higher absorption capacity. The increase in K content of leaf may be due to better establishment of plant on account of more nutrients in soil due to the application of higher dosage of N.

5.3.7 Calcium, Magnesium and Sulphur

The leaves obtained by the application of N @ 125 kg/ha/yr recorded higher calcium (2.985 ± 0.010%), magnesium (0.726 ± 0.017 %) and sulphur (0.359 ± 0.019%) when compared to application of N @ 100 and 75 kg/ha/yr (2.613 ± 0.070, 0.606 ± 0.026 and 0.260 ± 0.029%, respectively). Higher calcium, magnesium and sulphur contents with higher dose of N may be due to enhanced uptake of other macro and micro nutrients by mulberry.

The study indicated that the increased levels of N from 75 to 125 kg/ha/yr positively enhanced the yield and quality parameters of mulberry under rainfed condition.

5.4 INFLUENCE OF METHODS AND FREQUENCIES OF FEEDING RAINFED MULBERRY RAISED WITH DIFFERENT LEVELS OF NITROGEN (CAN) ON THE PERFORMANCE OF SILKWORM

5.4.1 Larval weight

In the present study, the larval weight in different instars differed significantly due to application of mulberry raised with different levels of N through different methods at varied frequencies. The larval weight was higher with the combination of 125 kg N/ha/yr x whole shoots x 5 feeds/day, whole shoots x 4 feeds/day, chopped shoots x 5 feeds/day, chopped shoots x 4 feeds/day and whole leaves x 5 feeds/day at same level of N. The larval weight exhibited positively significant relationship with foliar constituents viz., leaf moisture (r=0.9998), cholorophyll 'a' (r=0.9590), 'b' (r=0.9883), total chlorophyll (r=0.9743), total carbohydrates (r=0.9977), crude protein (r=0.9532), nitrogen (r=0.9538), phosphorus (r=0.9698), potassium (r=0.9994), calcium (r=0.9902), magnesium (r=0.9618) contents of mulberry raised with varied levels of N.

There was a direct relationship between increase in N level and the increase in larval weight. Sudo *et al.* (1981) also found highly significant correlation between N content (4-4.5%) in leaf and the larval weight. Mareppa (1999) found significant positive correlation between calcium, sulphur and total chlorophyll of mulberry leaf with larval weight. These results are also supported by the observations of Narayanan *et al.* (1966), Kasiviswanathan and Venkataramu (1973), Sidhu *et al.* (1969), Potdar (1994) and Sudharshana Reddy (1994). However, Kasiviswanathan *et al.* (1970) recorded non-significant difference in larval weight between two levels of N (100 and 200 kg/ha/yr).

The mulberry leaves intact with shoots were found to preserve the acceptability, turgidity and palatability of leaves leading to increased feeding efficiency of silkworm. The present results are in conformity with those of Chikkavenkateshappa (1987) and Muraleedhara (1990), according to whom the weight of ripened larva was significantly higher in the case of silkworms applied with the whole mulberry shoots with tender flush during August-September. Similar results were obtained previously (Krishnaswami *et al.*, 1970 ; Anon., 1986b, and Badiger, 1996). The present results are in agreement with the earlier report (Anon., 1983a) wherein, the average weight of ripened larva (NB_7xNB_{18}) was high (3.86g) when reared on chopped leaves throughout, compared to that of whole leaves upto third instar and then on shootlets till ripening stage (2.78g). The present results are also contradictory to those of Kasiviswanathan *et al.* (1970) who obtained higher weight of ripened larva of $PMxC_{108}$ (2.232g) when fed with plucked leaves, compared to that of shoot feeding (1.996g). Although the values vary very much, the trend has remained more or less similar and the variations noticed are attributable to the inherent capacity of silkworm races to produce silk coupled with the environmental factors.

With regard to feeding frequency, the results are in conformity with those of Krishnaswami *et al.* (1977) who observed more mature larval weight with 4 feeds/day with plucked leaves in chawki stage and shoot feeding from third instar compared to 5 or 6 feeds/day with plucked leaf throughout larval period. Similarly, Narasimhanna and Sudhakaran (1973) found that the feeding regime of 5 feeds a day was superior to the others and it resulted in increased larval weight. It was inferred that restricted feeding has resulted in reduced larval weight by 47 per cent under one feeding regime, whereas under 3 feedings regime the same was reduced to the tune of 13 per cent (Anon., 1983b). Similar facts were established earlier (Chandrashekar, 1996 ; Anon., 1969b and 1986b ; Krishnaswami *et al.*, 1980 and Das *et al.*, 1994). However, rearing of silkworms (Shungetsu Hosho) with different frequencies did not influence the larval weight (Anon., 1965).

5.4.2 Larval duration

Larval duration was found significantly shorter in whole shoot feeding from beginning to the end at a feeding frequency of 5 feeds/day in combination with leaves raised at 125 kg N/ha/yr together with whole shoots x 4 feeds/day, whole shoots x 3 feeds/day, chopped shoots x 5 feeds/day, chopped shoots x 4 feeds/day, chopped shoots x 3 feeds/day, whole leaves x 5 feeds/day, whole leaves x 4 feeds/day and whole leaves x 3 feeds/day. The duration was longer with N @ 75 kg/ha/yr x whole leaves x 3 feeds/day. Further, the larval duration had negatively significant correlation with leaf moisture (r=-0.9992), chlorophyll 'a' (r= -0.9740), 'b' (r=-0.9956), total chlorophyll (r=-0.9859), total carbohydrates (r=-0.9999), crude protein (r=-0.9693), nitrogen (r=-0.9678), phosphorus (r=-0.9538), potassium (r=-0.9958), calcium (r=-0.9967), magnesium (r=-0.9763) and sulphur (r=-0.9644). In general, the leaves raised with the application of N @ 125 kg/ha/yr were nutritionally superior over other levels, thus the silkworms fed on such leaves registered shorter larval duration.

The reduced larval duration with shoot feeding could be due to the mulberry leaves intact with shoots remaining fresh and palatable to silkworms for longer duration compared to chopped shoots and whole leaves where they dry up soon because of exposure of more surface area to atmosphere. Thus shoot feeding ensured efficient consumption of leaves by the silkworms (NB_4D_2) apart from better aeration, sufficient space for each worm this resulting in their good growth and early ripening thereby reducing the larval duration. Reduction in larval duration by 1 to 1.5 days in the case of shoot rearing was recorded due to better maintenance of moisture in leaf, which might have increased the rate of ingestion and digestion of silkworms. This is also because moisture acts as olfactory and gustatory stimulant, whereas the appetite of silkworms reduces when withered leaves are fed. Thus the moisture content of the leaves plays an important role in the growth and development of silkworms (Yokoyama, 1962b). These results are in line with those of Muraleedhara (1990), who reported shorter larval duration among silkworms given with whole shoots with tender flush as compared to 'check'. But the present findings disagree with that of Chikkavenkateshappa (1987), who found non-significant difference between different methods of feeding in respect of larval duration of silkworm (PM x NB_4D_2) and this difference may be due to the response of the silkworm breed tried and the chopped leaves offered to chawki worms.

The results on the feeding frequency of silkworm are supported by Haniffa *et al.* (1988) who reported that when the number of feeds were restricted from 8 to 1/day, the larval period was extended. Even in an experiment conducted to analyse the effect of varied number of feedings on the growth and cocoon yield of silkworm, the results indicated that restricted feeding had prolonged the larval duration (Anon., 1983b). Krishnaswami *et al.* (1980) also observed prolongation of larval period as a result of under feeding. The larval duration in the present study has almost followed the trend observed by the previous workers (Das *et al.*, 1994 ; Chandrashekar, 1996). The present observations are in agreement with the findings of Krishnaswami *et al.* (1977), according to whom 3 feedings with both entire and chopped leaves prolonged the larval duration, while 4 feeds/day with chopped leaves reduced the larval duration. The treatment of 4 feeds/day upto second instar followed by shoot feeding was found to be the best. The nutritional requirement of the silkworm has to be fulfilled both qualitatively and quantitatively so as to make it to mature and enter the next stage. Presently, among the N levels, feeding methods and frequencies, wherever there was provision for less N, in combination with whole leaves with 3 feeds/day in all the instars, the prolongation observed in the larval period may have to be attributable to the above fact.

5.4.3 Larval survival and ERR

The larval survival in different instars and ERR were significantly higher when silkworms were reared on whole shoots of mulberry raised with the application of 125 kg N/ha/yr in combination with feeding regime of 5 feeds a day together with whole shoots x 4 feeds/day, chopped shoots x 5 feeds/day, chopped shoots x 4 feeds/day, whole leaves x 5 feeds/day, whole shoots x 3 feeds/day and chopped shoots x 3 feeds/day. The least survival and ERR were found with 75 kg N/ha/yr x whole leaves x 3 feeds/day. The larval survival and ERR were found to have significantly positive relationship with leaf moisture (r=0.9995 and 0.9994), chlorophyll 'a' (r=0.9554 and 0.9551), 'b' (r=0.9863 and 0.9862), total chlorophyll (r=0.9715 and 0.9712), total carbohydrates (r=0.9967 and 0.9967), phosphorus (r=0.9727 and 0.9730), potassium (r= 0.9997 and 0.9998), calcium (r=0.9885 and 0.9883) and magnesium (r=0.9584 and 0.9581) contents of mulberry leaves. The results on the survival of larvae are in agreement with the observations of Samsijah (1985) and Venugopala Pillai *et al.* (1987) who recorded higher survival with increased level of N. Similarly, Mareppa (1999) found significant correlation between ERR with chlorophyll 'a', 'b' nitrogen, phosphorus and magnesium contents of mulberry leaves.

The increased ERR with whole shoots might be attributed to the fact that, the leaves attached to shoots were fresh for longer time and preserve the nutrients in the leaves resulting in higher survival of larvae with higher ERR. On the other hand, significantly lowest survival and ERR encountered with whole leaves and chopped shoots might be due to more moisture loss by chopping, quick dryness, high build up of humidity and temperature resulting in fermentation of leaves due to increased bed humidity, thus the worms suffering from poor nourishment. Further, the application of whole leaves and conventional method of feeding chopped shoots might not have reserved nutritional components due to disintegration of nutrients in the leaves unlike in shoot feeding. These results are in agreement with the findings of Chikkavenkateshappa (1987) who found higher ERR of 93.5 per cent in the case of silkworms supplied with whole shoots without tender flush during post-rainy season. Similarly, Muraleedhara (1990) recorded significantly higher ERR when silkworms were supplied with whole shoots with tender flush throughout during May-June, with an advantage of 20.86 per cent over check. These results are also in agreement with the observations of Krishnaswami *et al.* (1970), wherein significantly higher ERR (59.21%) was evident in MBD_5 silkworm breed reared on mulberry twigs with leaves compared to that of plucked leaves of a Local cultivar. Similar results were observed previously (Siddappaji *et al.*, 1992 ; Anon., 1986b) when silkworms were reared throughout with entire mulberry shoots.

In respect of feeding frequency, the present observations that increased number of feeds resulting in higher ERR have also been observed in that 5 or 6 feeds/day in late-age rearing resulted in better ERR (Anon., 1969b). Narasimhanna and Sudhakaran (1973) too observed higher ERR with 5 feeds/day compared to 2, 3 and 4 feeds/day. These current observations are also supported by the previous findings wherein, shoot feeding 4 times/day from third instar onwards resulted in higher ERR of 96.96 per cent compared to whole leaves (95.51%). Similar results as at present were observed in the past (Das *et al.*, 1994 ; Anon., 1983b).

5.4.4 Cocoon yield and Silk productivity

Silk productivity (cg/day) is a function of cocoon shell weight and fifth instar duration in days. Other than genetic control, these two are influenced to a greater extent by other factors such as rearing environment, quality and quantity of food etc. Hence, this parameter in the present investigation is of much relevance. Thus it has been considered as one of the characters to adjudge the optimum feeding frequency, method of feeding and N level. However, cocoon yield is the final indicator of the produce in terms of yield.

Among the levels of N tried, application of N @ 125 kg/ha/yr ; whole shoots among feeding methods and 5 feeds/day among feeding regimes were found best with regard to cocoon yield and silk productivity. However, least performance was observed with the interaction of 75 kg N/ha/yr x whole leaves x 3 feeds/day. The cocoon yield and silk productivity had significantly positive correlation with foliar constituents of mulberry raised with different levels of N. The foliar constituents viz., leaf moisture (r=0.9929 and 0.9729), chlorophyll 'a' (r=0.9888 and 0.9994), chlorophyll 'b' (r=0.9999 and 9951), total chlorophyll (r=0.9960 and r=0.9997), total carbohydrates (r=0.9976 and 0.9831), crude protein (r=0.9857 and 0.9985), nitrogen (r=0.9860 and 0.9986), potassium (r=0.9853 and 0.9592), calcium (r=0.9999 and 0.9936), magnesium (r=0.9903 and 0.9997) and sulphur (r=0.9823 and 0.9973) had positive correlation with cocoon yield and silk productivity, respectively.

Increase in cocoon yield and related characters with increase in N levels was mainly due to improvement in quality of leaves as evidenced by the correlation co-efficients. These findings are in agreement with the observations of Krishnaswami *et al.* (1971) and Venugopala Pillai (1987) who recorded higher cocoon yield and absolute silk contents with the application of N @ 900 kg/ha/yr. Similarly application of N at higher dosage favoured higher cocoon yield (Kasiviswanathan and Iyengar, 1971 and Potdar *et al.*, 1997a).

The present findings on feeding methods are in close conformity with those of Chikkavenkateshappa (1987) and Muraleedhara (1990) who obtained higher cocoon yields in case of $PMxNB_4D_2$ and NB_4D_2 silkworms reared on the whole shoots of mulberry without tender and with tender flush as compared to check, respectively. The previous observations (Siddappaji, 1986 ; Siddappaji *et al.*, 1992 and Anon., 1987a) lent support to the present findings on cocoon yield. Even in silkworm hybrids, $NB_{18}xNB_7$ and $PMxNB_{18}$ the schedule of 3 feeds/day in young-age followed by 4 feeds/day in late-age silkworm rearing resulted in higher cocoon yield (Anon., 1987b). It was observed previously that the cocoon yield/100 dfls throughout the seasons was higher when silkworms were reared from third instar and onwards with shoots at a feeding frequency of 4 feeds/day (Anon., 1986b).

5.4.5 Cocoon weight, Shell weight and Shell ratio

The combination of N levels, feeding methods and frequencies had a profound influence on cocoon traits of silkworm. Significantly higher cocoon weight, shell weight and shell ratio were observed with the combination of 125 kg N/ha/yr x whole shoots x 5 feeds/day together with whole shoots x 4 feeds/day, chopped shoots x 5 feeds/day, chopped shoots x 4 feeds/day, whole leaves x 5 feeds/day, whole shoots x 3 feeds/day and chopped shoots x 3 feeds/day at same level of N. However, it was least with 75 kg N/ha/yr x whole leaves x 3 feeds/day. The cocoon weight, pupal weight and shell ratio exhibited positively significant correlation with chlorophyll 'a' (r=0.9999, 0.9996 and 0.9963), 'b' (r=0.9924, 0.9864 and 0.9759), total chlorophyll (r=0.9988, 0.9959 and 0.9894), total carbohydrates (r=0.9783, 0.9689 and 0.9539), crude protein (r=0.9995, 0.9999 and 0.9978), nitrogen (r=0.9996, 0.9999 and 0.9977), calcium (r=0.9906, 0.9841 and 0.9728), magnesium (r=0.9999, 0.9992 and 0.9954) and sulphur (r=0.9988, 0.9999 and 0.9989) ; cocoon weight and shell weight with moisture (r=0.9669 and 0.9556) and cocoon weight with potassium (r=0.9519) contents of mulberry leaves, respectively.

The present findings are in line with the observations of Narayanan *et al.* (1966) as per whom the N fertilization could significantly increase the cocoon and shell weights and further the application of 200 kg N/ha/yr was not harmful to any of the cocoon characters. These results are also in conformity with those of Patra (1996) who observed superior cocoon characters with 150 kg N/ha/yr over 100 kg/ha/yr under rainfed condition. Sudo *et al.* (1981) found highly significant correlation between N content of mulberry leaf with cocoon and shell weights. However, non-significant difference was evident with respect to cocoon characters among different N levels (Kasiviswanathan *et al.*, 1970 ; Anon., 1976a ; Sengupta *et al.*, 1972 and 1973 ; Das *et al.*, 1993). Whereas, Potdar (1994), Sudharshana Reddy (1994) and Krishnaswami *et al.* (1971) obtained significant difference in cocoon characters with varied N levels under irrigated condition. Mareppa (1999) also found significant correlation between cocoon parameters with crude protein, total chlorophyll, N, K, Ca and S but negative correlation with moisture content of leaves.

The results are in close conformity with those of Chikkavenkateshappa (1987), who recorded superior cocoon parameters in silkworms (PM x NB_4D_2) supplied with the whole shoots without tender flush. Similarly, Muraleedhara (1990) and Badiger (1996) too found the same with whole shoots having apical tender flush. The present findings also corroborates with that of Krishnaswami *et al.* (1970) who recorded higher cocoon weight (0.95g), shell weight (0.133g) and shell ratio (14.1%) when silkworms were fed on mulberry twigs compared to plucked leaves (0.93g ; 0.127g and 13.6%, respectively). The present results are in close conformity with previous work (Anon., 1986b), wherein the application of chopped mulberry leaves to a multivoltine breed Nistari upto second instar and then whole shoots till ripening resulted in higher cocoon characters as compared to that of worms fed with plucked leaves throughout. These results are contradictory to the findings of Kasiviswanathan *et al.* (1970) who found slightly higher cocoon parameters when larvae of silkworm hybrid ($PMxC_{108}$) were fed with plucked mulberry leaves compared to that of shoot fed silkworms. Similarly, bivoltine silkworm hybrid (NB_7xNB_{18}) reared on chopped mulberry leaves resulted in higher cocoon weight, shell weight and shell ratio compared to that fed with shootlets during fourth and fifth instars. The difference in cocoon parameters may be attributable to the difference in the potentialities of the silkworm breeds reared.

The results of the present study on feeding frequency are in corroboration with the observations made by Narayanan and Chawla (1965) who recorded more cocoon and shell weights in both PM x Shungetsu Hosho with 5 feeds/day compared to 4 feeds/day. The superiority of 5 feeds/day compared to 2, 3 and 4 feeds/day in increasing the cocoon characters has been established by Narasimhanna and Sudhakaran (1973). These observations are also supported by the findings of Krishnaswami *et al.* (1977) who found that 4 feedings/day gave higher cocoon weight, shell weight and shell ratio than 3 feeds/day. Higher cocoon traits were also obtained in silkworm hybrid (Nistari x G) when it was reared with shoots in late instars (Anon., 1987b). Similarly, inferior cocoon characters resulted when silkworms were fed with less frequency (under feeding) (Krishnaswami, *et al.*, 1980 ; Jolly, 1981 ; and Anon., 1983b). Karaivanov (1990) also observed that decrease in the frequency of feeding at 1 to 2 feeds daily brought about certain decrease in cocoon characters. Rearing of silkworms on shoots 4 times/day had also resulted in higher cocoon weight, shell weight and shell ratio (Krishnaswami *et al.*, 1970) which tends to confirm the present observations. Silkworms rearing on shoot from third instar onwards with 4 feeds/day gave superior cocoon characters (Anon., 1986b) and the present observations yielding more cocoon weight, shell weight and shell ratio with increased number of application of shoots tally with these observations. Chandrashekar *et al.* (1999b) also reported higher cocoon parameters when silkworms ($PMxNB_4D_2$) were fed with shoots at a frequency of 3, 4 and 5 feeds/day.

5.4.6 Single cocoon Filament length and Denier

Single cocoon filament was longer from the cocoons spun by the worms fed on whole shoots of mulberry raised with 125 kg N/ha/yr at 5 times a day along with whole shoots x 4 feeds/day, chopped shoots x 5 feeds/day, chopped shoots x 4 feeds/day, whole leaves x 5 feeds/day and whole shoots x 3 feeds/day. However, shortest cocoon filament was noticed with 75 kg N/ha/yr x whole leaves x 3 feeds/day. Whereas, the denier of the filament was influenced only by N levels and not with feeding methods and frequencies. The foliar constituents of mulberry raised with varied N levels showed significantly positive relationship with filament length, while it was negative with denier. The correlation co-efficients for filament length and denier with foliar constituents viz., leaf moisture (r=0.9920 and -0.9948), chlorophyll 'b' (r=0.9999 and -0.9719), total chlorophyll (r=0.9966 and -0.9516), total carbohydrates (r=0.9971 and -0.9885), Potassium (r= 0.9840 and -0.9992) and calcium (r= 0.9999 and -0.9749) ; filament length with chlorophyll 'a' (r=0.9899), crude protein (r=0.9869), nitrogen (r= 0.9872), magnesium (r= 0.9913) and sulphur (r=0.9836) ; denier with phosphorus (r= -0.9875) contents of mulberry leaf were found to have relationship with each other.

These results are in line with those of Narayanan *et al.* (1966) who recorded superiority in respect of filament length and denier with increase in N application. While, Kasiviswanathan *et al.* (1970) and Kariviswanthan and Iyengar (1971) obtained increased filament with higher dose of N but denier of the filament was not influenced by N fertilization.

The results on feeding methods are in line with Chikkavenkateshappa (1987) who obtained longer cocoon filament and finer denier when silkworms were reared on entire shoots without tender flush. Similarly, Siddappaji *et al.* (1992) recorded longer filament and thinner denier with the application of mulberry twigs/entire shoots throughout the larval period. The above results also corroborate the findings of Badiger (1996). On the contrary, Kasiviswantathan *et al.* (1970) obtained longer filament with selective leaf feeding (507m) when compared to worms fed on whole shoots (440 m). Similarly, present results differ with the observations of Muraleedhara (1990) according to whom, significantly more filament was noticed in case of silkworms fed throughout with the whole mulberry leaves cut into two bits.

The results on the feeding frequency are in agreement with those of Narayanan and Chawla (1965) who observed longer filament and finer denier with 5 feeds/day as compared to 4 and 3 feeds/day in silkworm hybrid, PMx Shungetsu Hosho under feeding of silkworms at 1 to 2 feeds/day caused significant reduction in filament length compared to normal feeding (Anon., 1983b ; Karaivanov, 1990). Krishnaswami *et al.* (1977) have also obtained longer cocoon filament with 4 feeds/day than with 3 feeds/day and this supports the trend observed currently.

5.4.7 Fibroin and Sericin

Silkworms offered mulberry raised with different levels of N through different methods at varied frequencies of feedings exhibited influence on the secretion of sericin, while secretion of fibroin varied with N levels and not with method and frequency of feeding. The combination of 125 kg N/ha/yr x whole shoots x 5 feeds/day recorded higher fibroin content together with other methods and frequencies at same level of N. While the trend was similar for lower content of sericin. The fibroin and sericin contents showed significant relationship with foliar constituents viz., leaf moisture (r=0.9871 and -0.9866), chlorophyll 'a' (r=0.9941 and -0.9946), 'b' (r=0.9997 and -0.9996), total chlorophyll (r=0.9988 and -0.9991), total carbohydrates (r=0.9939 and -0.9934), crude protein (r=0.9918 and -0.9923), nitrogen (r=0.9920 and -0.9926), potassium (r=0.9773 and -0.9765), calcium (r=0.9993 and -0.9991), magnesium (r=0.9952 and -0.9956) and sulphur (r= 0.9892 and -0.9898) contents of mulberry raised at varied levels of N. Since, N being the basic elementary constituent of silk proteins (fibroin and sericin) its availability in higher amount in the leaf has significantly increased the silk synthesis in the silkworm resulting in higher content of fibroin in the silkglands which ultimately improved the shell weight of silk cocoons. The literature on the influence of method and frequency of feeding on fibroin and sericin contents is lacking.

5.4.8 Rate of pupation, Pupal weight and Pupal duration

Rate of pupation and pupal weight were significantly influenced by N levels, feeding methods and feeding regimes. The combination of 125 kg N/ha/yr x whole shoots x 5 feeds/day registered higher rate of pupation and pupal weight together with whole shoots x 4 feeds/day, chopped shoots x 5 feeds/day, chopped shoots x 4 feeds/day, whole leaves x 5 feeds/day, whole shoots x 3 feeds/day, whole leaves x 4 feeds/day, chopped shoots x 3 feeds/day and whole leaves x 3 feeds/day. However, silkworms that received whole mulberry leaves raised with 75 kg N/ha/yr in combination with 3 feeds/day recorded least rate of pupation and pupal weight. Whereas, the pupal duration was significantly influenced only by N levels and not due to feeding regimes and methods. The rate of pupation and pupal weight showed significant positive relationship with foliar constituents, while the trend was in reverse order for pupal duration where the relationship was negative for leaf moisture (r= 0.9856, 0.9771 and -0.9993), chlorophyll 'a' (r= 0.9951, 0.9986 and -0.9538), 'b' (r=0.9994, 0.9968 and -0.9855), total chlorophyll (r= 0.9992, 0.9999 and -0.9702), total carbohydrates (r=0.9928, 0.9864 and -0.9963), potassium (r=0.9754, 0.9644 and -0.9999), calcium (r=0.9988, 0.9956 and -0.9876) and magnesium (r=0.9961, 0.9990 and -0.9568) ; rate of pupation and pupal weight for crude protein (r=0.9930 and 0.9973), nitrogen (r=0.9932 and 0.9974) and sulphur (r=0.9905 and 0.9957) ; pupal duration for phosphorus (r= -0.9740) contents of mulberry leaves, respectively.

Documented literature on the effect of N levels, methods and frequencies of feeding and their combination is little and hence it limits discussion on the above results. The higher rate of pupation might be attributable to the fact that, as these pupae were formed from worms fed on nutritionally superior leaves grown with 125 kg N/ha/yr as evidenced by correlation co-efficients in combination with whole shoots fed 5 times a day and these results were also supported through higher survival and ERR in the same set of treatment combinations as discussed earlier. Nevertheless, it is a known fact that pupal weight is positively correlated with a cocoon weight contributing the major component of cocoon weight. It is also evident that the tendency of results with cocoon weight and larval duration follows more or less same trend as that of pupal weight and pupal duration, respectively. The results on pupal weight are of great significance from the view point of rearing silkworms both in production of seed cocoons as well as the commercial cocoons, as the fecundity of the silk moth is dependent on the pupal weight which indicates that feeding of silkworms through mulberry shoots raised with 125 kg N/ha/yr at 5 times a day may be adopted profitably.

5.4.9 Rate of moth emergence, Fecundity and Hatchability

Silkworms supplied with mulberry whole shoots corresponding to 125 kg N/ha/yr recorded higher rate of moth emergence, fecundity and hatchability along with whole shoots x 4 feeds/day, chopped shoots x 5 feeds/day, chopped shoots x 4 feeds/day, whole leaves x 5 feeds/day, whole shoots x 3 feeds/day, whole leaves x 4 feeds/day, chopped shoots x 3 feeds/day and whole leaves x 3 feeds/day at same level of N. However, worms fed on mulberry whole leaves 3 times a day with 75 kg N/ha/yr recorded least. Rate of moth emergence, fecundity and hatchability were found to have significant positive correlation with leaf moisture (r=0.9773, 0.9928 and 0.9886), chlorophyll 'a' (r=0.9984, 0.9889 and 0.9931), 'b' (r=0.9968, 0.9999 and 0.9999), total chlorophyll (r=0.9999, 0.9960 and 0.9984), total carbohydrates (r=0.9865, 0.9975 and 0.9948), crude protein (r= 0.9972, 0.9858 and 0.9906), nitrogen (r=0.9973, 0.9862 and 0.9909), Potassium (r=0.9646, 0.9851 and 0.9792), calcium (r=0.9957, 0.9999 and 0.9996), magnesium (r=0.9990, 0.9904 and 0.9942) and sulphur (r=0.9956, 0.9825 and 0.9878) contents of mulberry leaves raised with varied levels of N.

The observed superiority may be due to healthy and robust larvae which spun good cocoons with healthy pupae resulting in higher rate of moth emergence and fecundity. In respect of shoot feeding, the results are in accordance with the observations of Badiger (1996) with silkworms reared on mulberry whole shoots throughout the larval period.

5.5 ECONOMICS OF RAINFED MULBERRY PRODUCTION PER HECTARE UNDER DIFFERENT LEVELS OF NITROGEN (CAN)

Cost of mulberry production differed with varied N levels and it was higher with 125 kg/ha/yr (Rs.18,077), of which cost of N accounted for Rs.3,200, followed by 100 (Rs.17,437 and 2,560) and 75 kg/ha/yr (Rs.16,797 and 1,920), respectively. Similarly, gross profit and net profit were more with 125 kg N/ha/yr (Rs.22,446 and 4,368) and least with 75 kg N/ha/yr (Rs.19,179 and 2,381). In respect of benefit : cost ratio, for every rupee spent on mulberry production the benefit was 24.2 paise in case of 125 kg N/ha/yr, followed by 100 (22.4 paise) and least with 75 kg N/ha/yr (14.2 paise). The study indicated that the cost of production of mulberry decreased with increased levels of N that consequently increased the benefit per rupee spent on it. These results are in agreement with a previous report (Anon., 1973d) wherein, the cost of production was lower with the application of N @ 100 kg/ha/yr (18.8 paise/kg leaf) over control (22.9 paise) under rainfed condition. Similarly, variation in the cost of mulberry production and returns from mulberry under irrigated condition were reported (Kasiviswanathan *et al.*, 1979 ; Anon., 1976c and 1984c ; Rajanna and Dandin, 1993). The differences might be attributable to the variation in the system of mulberry cultivation, cost of inputs and final yield etc.

5.6 INFLUENCE OF NITROGEN (CAN) LEVELS, METHODS AND FREQUENCIES OF FEEDING ON ECONOMICS OF COCOON PRODUCTION FOR 100 DFLs

5.6.1 Mulberry leaf (Quantity and Cost)

The estimated quantity of leaf consumption was higher with whole shoots of mulberry raised at 125 kg N/ha/yr with regime of 5 feeds a day (865 kg) together with whole shoots x 4 feeds/day, chopped shoots x 5 and 4 feeds/day, whole shoots x 3 feeds/day, chopped shoots x 3 feeds/day and whole leaves x 3 feeds/day. While the consumption was lower with whole leaves x 3 feeds/day (735 kg). However, the cost of leaf was higher with 75 kg N/ha/yr x whole shoots x 5 feeds/day (Rs.1054) and was lower with 100 kg N/ha/yr x whole leaves x 3 feeds/day (Rs.909). The higher consumption of leaf with higher nitrogen, whole shoots and increased frequency might be attributed to the leaves intact with shoots remaining fresh and acceptability to silkworms was longer, hence the feeding period in the rearing bed lasted longer and larvae consume more quantity and this inturn helped for the optimum growth and development of silkworms and improved the cocoon characters in these treatments. On the other hand, lower consumption of mulberry with whole leaves raised with less N (75 kg/ha/yr) and reduced feeding frequency contributed for withering of leaves at faster rate resulting in wastage of leaves and further the growth and development of silkworms and cocoon characters were inferior with these treatments. Further, increased cost of production of mulberry at 75 kg N/ha/yr contributed for higher cost of leaf. These results are in agreement with Muraleedhara (1990) who recorded higher consumption of leaves with whole shoots with tender flush (720 kg/100 dfls) and chopped shoots with tender flush (686.5 kg) and lower with whole shoots without tender flush (677 kg) and the corresponding cost was Rs. 432.0, 411.9 and 406.2, respectively. Similar results are common (chikkavenkateshappa, 1987 ; Anon., 1972 ; Yokoyama, 1962b). However, variation found in quantity of leaf consumption and cost of leaf might be attributable to the fact that, in the present study the varied levels of N and varied frequencies of feeding tried have contributed for the difference and the literature on these aspects is not available for discussion.

5.6.2. Labour (Quantity and cost)

The labour requirement was less with whole shoots fed 3 times a day (21.00, 21.05 and 21.05 mandays) and the corresponding cost was Rs. 1050, 1055 and 1052 together with whole shoots x 4 feeds/day, chopped shoots x 3 feeds/day and chopped shoots x 4 feeds/day at 75, 100 and 125 kg N/ha/yr, respectively. However, labour requirement and cost was more with whole leaves fed 5 times a day at all levels of N. The higher labour requirement and cost of labour in the case of whole leaves may be due to more time needed to select and pluck the individual leaves from the standing crop compared to that of shoot harvest, more time to feed the worms with whole individual leaves and the additional time consumed for cleaning the rearing bed compared to shoot feeding. These results are in agreement with those of chikkavenkateshappa (1987) who found that the labour requirement was least (17.90 mandays and Rs. 179.19) in the case of the whole shoots without tender fulsh offered to silkworms

(December-January), followed by 18.19 mandays and Rs.182.33 during August- September, compared to that of 24.8 mandays and Rs. 248.35, 27.29 mandays and Rs.273.5 during rainy and post rainy seasons, respectively. The present findings also corroborates with those of Muraleedhara (1990) who recorded per cent advantage of 28.38, 14.95 and 15.70 with whole shoots with tender flush (August-September and May-June) and whole shoots without tender flush (January-February), respectively. Further as per Yokoyama (1962b), 20 per cent reduction in the labour requirement results when worms are fed on shoots during fourth and fifth instars. These results are also in accordance with previous work (Narasimhamurthy and Subramanyam, 1988 ; Anon., 1972 and 1975d).

5.6.3 Total cost of production

The estimated cost of silk cocoon production was less (Rs.3720) in case of whole shoots fed at a frequency of 3 times a day at 75 kg N/ha/yr along with 100 kg N/ha/yr x whole shoots x 3 feeds/day (Rs. 3724) and 125 kg N/ha/yr x whole shoots x 3 feeds/day (Rs.3732). However, the cost of production was more with 125 kg N/ha/yr x whole leaves x 5 feeds/day (Rs.4214). The incremental cost of cocoon production in the case of the latter treatment was due to additional labour involved for harvesting mulberry leaves, preparation of leaf material for feeding worms and increased frequency of feeding as compared to that of the entire shoots fed at 3 times a day. The present results are in close conformity with the findings of chikkavenkateshappa (1987) who found that the cost of cocoon production for 100 layings was least (Rs. 597.27) in the case of chopped shoots in rainy season, followed by Rs. 615.47 with the whole shoots with tender flush applied to silkworms ($PMxNB_4D_2$) during post-rainy season. The difference noticed is attributable to higher leaf requirement for the bivoltine breed (NB_4D_2) used in the present investigation, which factor in turn is responsible for relatively higher cost of production compared to that of cross breed (PMxNB$_4$D$_2$) tried in earlier studies. Similarly, Muraleedhara (1990) recorded advantage of 56.35, 30.61 and 40.93 per cent when silkworms were reared on whole shoots with tender flush during January-February, August-September and May-June, respectively. These results are also in agreement with those of Narasimhamurthy and Subramanyam (1988), Kumar and Benchamin (1990) and Shekharappa *et al.* (1991) who recorded less cost of production with whole shoot feeding over leaf feeding.

5.6.4 Cocoon yield (Quantity and cost)

The estimated cocoon yield and cost of cocoons per 100 layings were higher with whole shoots corresponding to 125 kg N/ha/yr fed 5 times a day (77.62 kg and Rs.13,583) along with whole shoots x 4 feeds/day (76.82 kg and Rs.13,443) and chopped shoots x 5 feeds/days (76.68 kg and Rs.13,419). However, it was lower for 75 kg N/ha/yr x whole leaves x 3 feeds/day (45.42 kg and Rs.7,948). The discussion part on cocoon yield is included under cocoon yield per box of eggs. The increased gross profit is mainly attributed to the fact that feeding of silkworms with whole shoots raised with higher level of N and at higher frequency yielded more cocoons and resulted in higher value for cocoons with respective treatments.

5.6.5 Net profit

The net profit derived was higher in the case of silkworms reared on whole shoots raised at 125 kg N/ha/yr with a feeding frequency of 5 feeds/day (Rs.9,685) along with whole shoots x 4 feeds/day (Rs. 9,624) and chopped shoots x 5 feeds/day (Rs.9,423). The profit was lower with 75 kg N/ha/yr x whole leaves x 3 feeds/day

(Rs.4,009). The variation in the profit realised among the treatments is attributable to higher cost of labour and low cocoon yields mostly coupled with the risk factors as a common feature in any biological production system. These results are in agreement with those of chikkavenkateshappa (1987) who obtained a higher profit in case of rearing with whole silkworm hybrid, $PMxNB_4D_2$ shoots without tender flush while Muraleedhara (1990) recorded higher net profit with whole shoots with tender flush.

5.6.6 B : C ratio

The B:C ratio was higher in the case of silkworms reared on the whole mulberry shoots raised with 125 kg N/ha/yr in combination with 4 feeds/day (2.520 :1) together with 5 (2.485 : 1) and 3 feeds/day (2.479 : 1) with same method and level of N. However, B : C ratio was lower with 75 kg N/ha/yr x whole leaves x 3 feeds/day (1.017 : 1). The more B:C ratio in the case of whole shoots raised with 125 kg/ha/yr is due to decreased cost of production by way of reduced cost of inputs (labour and resources including mulberry leaves) and increased output (cocoon yield). These results are in close conformity with the findings of Chikkavenkateshsppa (1987) who found higher B:C ratio of 2.33:1 in the case of silkworms ($PMxNB_4D_2$) supplied with whole shoots without tender flush as compared to that of the whole leaves and check. Similarly, Muraleedhara (1990) obtained higher B:C ratio (4.58:1) with the silkworms (NB_4D_2) reared on whole mulberry shoots with tender flush applied throughout the larval stage, while it was least (0.47:1) in the case of whole leaves cut into two bits. The higher B:C ratio is attributed to the fact that, the variables like mulberry leaf, labour and cost of layings were only taken into account for calculating the economics of silk cocoon production which resulted in higher B:C ratio. Further, the survey on cocoon crop production with shoot feeding indicated that, the B:C ratio for shoot feeding was 1.82 :1 over leaf feeding (Chandrappa *et al.*, 1999).

FUTURE LINE OF WORK

1. Although N is a primary nutrient limiting mulberry production, P and K together with N can further increase the leaf yield and quality. Studies on the response of mulberry to other nutrients like P and K and their interaction with N need to be investigated.
2. Plant tissue analysis needs to be studied for the benefit of sericulture industry as it is an advisory tool. Critical concentrations of nutrients in mulberry leaf need to be identified for guiding the fertilizer application practices.
3. Studies on integrated soil fertility management involving fertilizers viz., bio-fertilizers, organic manures, green manures and crop residues should be undertaken under rainfed condition.
4. Since moisture is the limiting factor in rainfed condition, critical level of soil moisture status has to be studied for the practical application of chemical fertilizers to mulberry in rainfed ecosystem.
5. The economic viability of feeding mulberry shoots raised with higher dose of N should be studied on commercial scale using the ruling silkworm hybrid, $PMxNB_4D_2$.
6. The present investigations were carried out with M_5 mulberry variety. Of late some mulberry genotypes viz., S_{13}, S_{34}, RFS_{-135} and RFS_{-175} suitable for rainfed conditions have been evolved and it may be necessary to extend the current study even to them so as to search for the technology with higher B:C ratio.

SUMMARY

VI. SUMMARY

The results of the experiments carried out on the "Effect of nitrogen levels on yield and quality of rainfed mulberry in relation to performance of silkworm with different methods and regimes of feeding" are summarised below.

The efficacy of four sources of nitrogenous fertilizers was evaluated initially for their influence on mulberry and silkworm. The mulberry supplied with nitrogen through CAN recorded significantly higher leaf yield (2.407 kg/10 plants and 14,440 kg/ha/yr), chlorophyll 'a' (1.726 mg/g), chlorophyll 'b' (0.958 mg/g) and total chlorophyll (2.684 mg/g), total carbohydrates (19.89%), crude protein (20.38%), nitrogen (3.261%), phosphorus (0.594%), potassium (2.193%), calcium (3.028%), magnesium (0.706%) and sulphur (0.358%), while leaf moisture was higher with urea (73.82%). Silkworms fed with mulberry raised through CAN application recorded significantly higher mature larval wiehgt (41.52 g/10), larval survival (94.60%), ERR (91.40%), cocoon yield (36.75 kg/box of 50 dfls), silk productivity (5.298 cg/day), cocoon weight (21.31 g/10), shell weight (4.450 g/10), shell ratio (20.88%), single cocoon filament length (1144m), fibroin (78.14%), rate of pupation (96.44%), pupal weight (16.30 g/10), rate of moth emergence (96.48%), fecundity (546.4 eggs/laying) and hatchability (94.31%) and least total larval duration (26.40 days), sericin (20.83%) and pupal duration (11.50 days) and were lowest with control. Thus CAN was found best for mulberry and silkworm.

Mulberry receiving N @ 125 kg/ha/yr through CAN recorded the highest leaf yield (2.494 ± 0.154 kg/10 plants and 14,964 ± 921.0 kg/ha/yr), leaf moisture (72.08 ± 0.400), chlorophyll 'a' (1.748 ± 0.029

mg/g), chlorophyll 'b' (0.982 ± 0.012 mg/g), total chlorophyll (2.730 ± 0.041mg/g), total carbohydrates (21.33 ± 0.478%), crude protein (21.26 ± 0.345%), nitrogen (3.403 ± 0.055%), phosphorus (0.624 ± 0.018%), potassium (2.314 ± 0.040%), calcium (2.985 ± 0.010%), magnesium (0.726 ± 0.017%) and sulphur (0.359 ±_0.019%) over 100 and 75 kg N/ha/yr supplied through CAN.

Silkworms fed with whole shoots of mulberry raised with 125 kg N/ha/yr through CAN, 5 times a day recorded significantly higher mature larval weight (44.83 g/10).

Combinations viz., whole shoots x 3, 4 and 5 feeds/day ; chopped shoots x 4 and 5 feeds/day ; whole leaves x 5 feeds/day registered in less duration of fifth instar (8.33 days) and total larval duration (25.32 days).

The combination of 125 kg N/ha/yr x whole shoots x 5 feeds/day recorded more larval survival during fourth (96.00%) and fifth instars (93.00%).

Significantly higher ERR (90.67%), cocoon yield (38.81 kg/box of 50 dfls) and silk productivity (5.345 cg/day) were obtained with the worms fed on mulberry whole shoots raised with 125 kg N/ha/yr at a feeding regime of 5 feeds a day and were lower with 75 kg N/ha/yr x whole leaves x 3 feeds/day (74.50%, 22.71 kg and 2.607 cg, respectively).

The silkworms supplied with mulberry through whole shoots grown under 125 kg N/ha/yr with a feeding frequency of 5 feeds/day yielded more cocoon weight (22.37 g/10), shell weight (4.452 g/10), shell ratio (19.90%), longer cocoon filament (1169 m), thinner denier

(2.447), more fibroin (78.29%) and less sericin (20.60%), while these were inferior with the batches of worms reared on whole mulberry leaves raised with 75 kg N/ha/yr at a feeding frequency of 3 feeds a day.

Significantly higher rate of pupation (96.80%) was observed in the combination of whole shoots corresponding to 125 kg N/ha/yr x 4 and 5 feeds/day and chopped shoots x 5 feeds/day, while the combination of 125 kg N/ha/yr x whole shoots x 5 feeds/day recorded higher pupal weight (17.84 g/10). However, the interaction of 75 kg N/ha/yr x whole leaves x 3 feeds/day registered lower rate of pupation (86.00%) and pupal weight (14.52 g/10). Pupal duration was seldom influenced by N levels, methods and frequencies of feeding.

The interaction of 125 kg N/ha/yr x whole shoots x 5 feeds/day along with 4 feeds/day at same N level and method of feeding recorded higher rate of moth emergence (96.40%). Fecundity (569.5 eggs/laying) and hatchability (95.85%) were highest with 125 kg N/ha/yr x whole shoots x feeds/day. However, these were least with 75 kg N/ha/yr x whole leaves x 3 feeds/day (87.00%, 478.1 eggs and 88.50%, respectively).

Positive correlation existed between larval weight, larval survival, ERR, cocoon yield, silk productivity, cocoon weight, shell weight, shell ratio, single cocoon filament length, fibroin, rate of pupation, pupal weight, rate of moth emergence, fecundity and hatchability with moisture, chlorophyll 'a' 'b' and total chlorophyll, total carbohydrates, crude protein, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur contents of mulberry leaves raised with different levels of N. However, the trend was negative for larval duration, denier, sericin and pupal duration.

Mulberry receiving N @ 75 kg/ha/yr recorded least cost of production (Rs.16,797/ha), while that with 125 kg N/ha/yr yielded higher gross profit of Rs.22,446, net profit of Rs.4,368 and B:C ratio of 0.242 : 1 over 100 and 75 kg N/ha/yr.

The cost towards mulberry was higher with 75 kg N/ha/yr x whole shoots x 5 feeds/day (Rs.1,054/100dfls) and was lower with 100 kg N/ha/yr x whole leaves x 3 feeds/day (Rs.909). Labour requirement and total cost of production per 100 dfls was less with whole shoots raised with 75 (21.00 md and Rs.3,720), 100 (21.10 md and Rs.3,724) and 125 kg/ha/yr (21.05 md and Rs.3,732) fed 3 times a day, while it was more with whole leaves x 5 feeds/day (30.65 md and Rs.4,189 ; 30.45 md and Rs.4,184 ; 30.52 md and Rs.4,214, respectively) at same levels of N.

The combination of 125 kg N/ha/yr x whole shoots x 5 feeds/day recorded more cocoon yield (77.62 kg/100 dfls), gross profit (Rs.13,583) and net profit (Rs.9,685), whereas least values were encountered with 75 kg N/ha/yr x whole leaves x 3 feeds/day (45.42 kg, Rs.7,948 and Rs.4,009, respectively). The B:C ratio was more with worms fed on whole shoots raised with 125 kg N/ha/yr at a feeding regime of 4 feeds/day (2.520:1) together with 5 feeds/day (2.485:1) and 3 feeds/day (2.479:1) at same level of N and feeding method. However, B:C ratio was less with 75 kg N/ha x whole leaves x 3 feeds/day (1.017:1).

It is thus inferred that, from the economic point of view, rearing NB_4D_2 breed of silkworms with M_5 mulberry, the whole shoots raised with 125 kg N/ha/yr under rainfed condition at a feeding regime of 3 feeds a day yields more profit.

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* Originals not seen

APPENDICES

Appendix – I

Monthly mean of weather parameters during cropping period at UAS, GKVK, Bangalore

Year/ Month	Temperature(°C)		Relative humidity (%)		Total rainfall (mm)	Wind velocity (m/hr)	Sun - Shine (hr)	Evapor-ation (mm/day)
	Maximum (07.00h)	Minimum (14.00h)	Morning (07.00h)	Noon (14.00h)				
1998								
July	27.7	19.7	87	56	132.2	10.3	3.1	3.9
August	27.4	19.6	91	60	352.2	6.8	4.2	3.6
September	27.1	19.4	90	63	245.7	6.7	4.2	3.7
October	27.1	18.6	91	61	241.7	5.6	4.5	3.4
November	26.6	16.9	87	60	37.5	5.4	6.4	3.2
December	25.7	15.3	90	58	14.7	7.3	5.8	3.2
1999								
January	27.0	13.6	75	47	0.0	6.3	8.6	4.5
February	29.2	15.4	77	41	7.8	9.0	9.3	6.1
March	32.9	17.6	59	30	0.0	5.1	9.5	7.6
April	33.3	19.5	81	34	53.8	8.0	8.7	6.9
May	30.3	19.4	90	50	154.3	8.1	7.2	5.8
June	28.7	18.5	89	54	95.2	11.4	6.6	5.4
July	28.0	19.0	89	58	49.4	11.5	3.8	4.3
August	27.7	19.4	91	60	205.8	9.3	4.3	4.2
September	28.5	19.1	89	55	238.7	7.5	6.6	4.1
October	27.0	19.5	92	63	196.8	5.4	5.0	3.1
November	26.0	16.5	84	57	71.2	6.6	6.2	4.0
December	25.0	14.4	92	58	18.2	6.4	6.4	3.5
2000								
January	27.2	14.1	88	46	0.0	7.2	8.5	4.4
February	28.6	16.4	88	49	133.2	6.3	7.0	4.8

Appendix – II

Weekly mean of temperature and relative humidity in silkworm rearing room, Department of Sericulture, UAS, GKVK, Bangalore

Week	Temperature (°C)		Relative humidity (%)
	Maximum	Minimum	
I Rearing (1998)			
September 3-9	26.0	22.0	77.0
10-16	25.5	23.0	80.0
17-23	26.0	23.0	78.0
24-30	26.0	22.5	79.0
October 1-7	25.0	23.0	79.0
8-14	26.0	22.0	77.0
15-21	24.5	21.5	81.0
22-28	25.0	22.0	80.0
II Rearing (1999)			
September 3-9	25.0	22.0	78.0
10-16	24.5	22.0	77.0
17-23	26.0	23.0	78.0
24-30	25.5	22.5	80.0
October 1-7	26.0	22.5	79.0
8-14	25.5	22.0	78.0
15-21	26.0	21.5	81.0
22-28	25.5	22.5	80.0
III Rearing (2000)			
January 4-10	24.0	22.0	81.0
11-17	24.0	23.0	79.0
18-24	25.0	22.0	78.0
25-31	26.0	22.0	80.0
February 1-7	25.0	22.0	78.0
8-14	25.0	22.0	82.0
10-21	26.0	22.5	79.0
22-28	25.0	22.0	80.0

Appendix – III

Cost of mulberry production per hectare

Sl. No.	Operation		Requirements	Rate (Rs.)	Amount (Rs.)
1	Ploughing		4times/4pairs at a time (16 pairs)	80/pair	1280.00
2	Harrowing		2times/4pairs at a time (8 pairs)	80/pair	640.00
3	Weeding around the plants		20 mandays	50/manday	1000.00
4	Farm yard manure (FYM)		10 tonnes	150/tonnes	1500.00
5	Application of FYM		8 mandays	50/manday	800.00
6	Cost of fertilizers (excluding nitrogen)				
	a	Phosphorus (SSP)	50 kg/ha/yr (312.5 kg)	2.98/kg	931.25
	b	Potassium (MOP)	50 kg/ha/yr (83.33 kg)	3.86/kg	321.65
7	Application of fertilizers		4 mandays	50/manday	200.00
8	Harvesting of leaves		10 mandays	50/manday	5500.00
9	Pruning		25 mandays	50/manday	1250.00
10	Non-recurring expenditure				1830.00
11	Land revenue				25.00
				Total	**14877.90**

Appendix – IV

Cost of silkworm rearing for 100 DFLs

Sl. No.	Particulars	Amount (Rs.)
1.	Cost of disease free layings	200.00
2.	Cost of disinfectants (Formalin, Bleaching Powder etc.)	150.00
3.	Cost of paraffin paper and foam rubber strips	100.00
4.	Cost of chemicals and bed disinfectants	150.00
5.	Non – recurring expenditure on rearing Equipments and mountages	720.00
6.	Depreciation value on building	225.00
7	Cost of transportation and marketing of cocoons	100.00
	Total	**1645.00**