New Technology of Silkworm Rearing

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CENTRAL SILK BOARD

NEW TECHNOLOGY OF SILKWORM REARING

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CONTENTS

I. INTRODUCTION

The practice of Sericulture comprises of two major activities namely cultivation of mulberry for raising the leaf crop to feed the silkworm and rearing of silkworms to produce the cocoons which is the raw material for the silk reeling industry. Mulberry cultivation is agricultural in nature, the operations involved being simple, straight and easy to be carried out. On the other hand, silkworm rearing is a quite complicated process, calling for a great management skill with due understanding of the various technical aspects involved. The silkworm which has been domesticated and evolved over many thousands of generations, to produce substantial quantities of silk in a very short period, is indeed very delicate and requires careful handling during the process of rearing. Highly productive races are still more delicate and demanding in their ecological requirements. Therefore, the job of raising highly productive silkworms in tropical areas as in South India is really tough.

Indian Sericulture in the past has been characterised by either poor cocoon crop yields or even total loss on certain occasions. Until 1970, the average yield of cocoons for 100 disease free layings (comprising roughly about 40,000 eggs) was of the order of only 20–25 kgs. as against 60–65 kgs. in temperate regions like Japan, Korea, USSR etc. Further, one out of every three or four crops used to result in total loss for the sericulturist. An analysis of the poor cocoon crop results in India indicated low values for the two important components that go to make the yield, namely, the number of cocoons harvested per laying and the average weight of the cocoon. In the past, only about 50 per cent of the hatched larvae in a laying spun the cocoons successfully and the average cocoon weight was hardly 1 to 1·25 gms. Therefore, in a laying of about 400 eggs, only about 200 cocoons were harvested which gave a yield of 200 to 250 gms. In other words, the yield was of the order of 20 to 25 kgs. per 100 disease free layings. If only these two components could be improved by 50 per cent individually, the combined effect will result in the number of cocoons harvested from a laying going upto 75 per cent or 300 cocoons and the average cocoon weight to 1·7 gms. That is to say, from a laying 300 cocoons weighing in all 510 gms. can be obtained; *i.e.* 51 kgs. from 100 disease free layings which would mean doubling the prevailing cocoon yields. If the layings are richer and the average number of eggs present goes upto 500, the yield will also correspondingly increase from 51 kgs. to 63·25 kgs. per 100 disease free layings. It can go still higher, if the number of cocoons

harvested from a laying could be stepped up further, beyond 75%. Thus, the key to bumper cocoon harvests lies in the skill of management of silkworm rearing aimed at achieving higher values for the above two components, namely, increased number of cocoons from a laying and higher cocoon weight.

Towards this end, serious research was initiated by the author first at Central Sericultural Research Station, Berhampore and later at Central Sericultural Research and Training Institute, Mysore. Based on the results achieved, the first paper on "Some Aspects of Improved Technique of Rearing for Mulberry Silkworm" was published in 'Indian Silk' * in 1971. This improved technique has been since popularised on a large scale during the last seven years in South India. As a result, it has been possible for the sericulturists adopting the new technique to step up the average yields from the earlier level of 20–25 kgs. to 30–40 kgs. at present. Also, total loss of one crop out of every 3–4 crops experienced earlier has been considerably reduced. Besides, introduction of highly productive bivoltine hybrids for producing reeling cocoons in the traditionally multivoltine areas of tropics became possible. Again, it is the new technique, which has helped in the recent past to extend sericulture to new areas in North Karnataka, Andhra Pradesh and Tamil Nadu, till recently considered as unsuitable for sericulture because of the high temperature and/or high humidity.

Although, to a large extent, the new technique has been fairly understood and practised by a good number of sericulturists today, need still exists to educate them further and also others who are yet to take to it, so that the averagae crop yields could be further improved to the level of 40–50 kgs. for 100 disease free layings. With this object in view, this paper on "**New Technology of Silkworm Rearing**" is being published as Bulletin No. 2 of the Institute, with necessary revision so that full significance of the various recommendations made in regard to silkworm rearing could be properly appreciated and practised (without inadvertant lapses) by the sericulturists. These recommendations, when followed systematically, will ensure optimum cocoon yields, practically in all the seasons.

II. TECHNICAL ASPECTS

The various technical aspects involved and the details of procedures to be followed in silkworm rearing are discussed below.

i) Rearing House:

The first pre-requisite is a fairly satisfactory room or house for rearing silkworms which should have adequate number of windows, ensuring free cross ventilation. It should also be possible to make it reasonably air tight to facilitate effective disinfection of the room/house, when required. The roof should have sufficiently high ceiling, upto 10' or so, so that wide fluctuations of temperature outside the room do not affect the conditions inside very much. Although such ideal requirements cannot be afforded by every sericulturist (who is normally a poor or marginal farmer) it should be the goal to

* Monthly Publication of Central Silk Board, Bangalore.

try to have a separate rearing house, satisfying the above specifications. The State Departments of Sericulture have drawn up special schemes to assist the sericulturist by way of subsidies and loans on easy terms in this regard and therefore, every sericulturist who does not possess a separate room or house for silkworm rearing should avail this assistance.

ii) Environmental Requirements:

The atmospheric temperature and humidity have a great bearing on the growth and health of the silkworms. The ideal temperature – humidity conditions under which the silkworms thrive best are 24° to 27°C and 70% to 90% relative humidity. The young age worms require higher temperature and humidity and the late age worms, lower temperature and humidity within the above range. But these are hardly obtainable in nature, particularly in the tropical zone of South India, where the temperature shoots upto over 30°C in summer and drops below 20°C during the rainy/winter seasons. Similarly, the humidity also fluctuates widely not only from season to season but also within the day itself during any season. Yet, it should be the endeavour of every sericulturist to bring the rearing room temperature/humidity conditions as close as possible to the ideal requirements of the silkworm. This can be achieved within reasonable limits by manipulating the ventilation within the room.

For instance, during summer, when the day temperature goes very high, all the Windows should be kept open during night. This enables the room temperature to come down. Further, all the windows and doors should be opened very early in the morning so that the cooler air from outside is allowed to blow freely inside and bring down the temperature to optimum levels. Thereafter, as the sun rises and the outside temperature goes up, the doors and windows should be closed (at about 9–10 a.m.) to keep out the heat and thereby, maintain the rearing room temperature as low as possible. Similarly, during the colder seasons, the doors and windows should kept closed during nights to keep out the cold and later in the day, as the outside temperature goes up, they should be opened to allow warm air to get in. In the same way humidity of the room also can be controlled by closing the doors and windows when it rains to keep out humidity and opening them when the rains have stopped to let in free blowing air to bring down the humidity.

During colder months, as in December – January, if the temperature falls too low necessary steps to raise the temperature to the desired level should be taken through artificial heating of the rooms with the aid of electric room heaters or smokeless charcoal fire. This is particularly necessary at the "**chawki**" (young age) stage rearing.

The above steps go a long way to provide the near-ideal environmental conditions for the silkworm to grow and thrive well. It is in this context, the need for a suitable rearing room or house conforming to the bare minimum specifications described above will be found unavoidable.

iii) Quality of Leaves:

Another major factor to be taken into consideration in silkworm rearing is the quality of leaf, because growth of the silkworm very much depends on the quality of leaves fed to it. The leaves best relished and utilised are those containing more moisture, protein, sugars and carbohydrates and less ash and fibre. They look both succulent and dark green in colour. Such good quality leaves can be obtained only from mulberry fields that are managed well, adopting optimum agronomic practices like application of manures and fertilisers, timely and correct way of irrigation, intercultivation etc., including suitable moisture conservation measures in the case of rainfed gardens, as described in Bulletin No. 1 of the Institute. In about 2 to $2^1/_2$ months time following pruning or last picking of leaves, the plants get covered with leaves that would have reached correct stage of maturity to be plucked and fed to the silkworms in the last instar. Therefore, commencing of rearing should be so timed that bulk of the harvest is made and utilised at the correct stage of leaf maturity, before the leaves get either overmatured or turn yellow and shed. Thus, timely harvest of leaves ensures both higher leaf yield (without loss due to yellowing and shedding) and better quality of leaves for feeding silkworms (avoiding deterioration in quality due to over maturity).

Further, for vigorous and uniform development of the worms it is also important to see that the leaf quality does not differ widely in the leaf harvest. Overmature and yellowing leaves are very poor in quality and therefore, these should be meticulously avoided while harvesting. Those inadvertantly got mixed should be picked out at the time of feeding. In the case of row system of cultivation, where the whole shoot method of harvesting leaves is practised, the harvest carries with it the very tender terminal growing parts of the plant as well. The latter varies in quality considerably from the rest of the leaves, containing too much moisture. It is, therefore, advisable to clip these terminal buds about a week prior to the harvest, so that these does not come alongwith the leaf harvest and also the rest of the leaves may attain more uniformity in quality.

The quality of leaf may also vary considerably from season to season, being influenced by the climatic factors. In the hot dry season, the leaves grow and mature fast, but wither quickly. Its life in the rearing bed is short necessitating upto five feeds or even six feeds per day during the hot dry months. In the rainy season, however, although the leaves grow and mature fast, they contain more moisture. Their life in the rearing bed lasts longer and therefore, three to four feeds per day may be found adequate. Because of the higher moisture content, they tend to increase the humidity of the bed beyond the tolerance point and therefore, it will be found necessary to keep the humidity of the bed under control, through feeding of reduced quantity of leaf and more mature leaf containing less moisture. In fact, during rainy season, it is advisable to use one stage more matured leaves while feeding each of the instars. That is to say, what is considered under normal circumstances as second age leaves should be fed to first instar larvae and the normal third age leaves to the second instar larvae and so on. In such seasons maintaining good ventilation in the rearing rooms is very essential.

It is also advisable to keep the rearing trays or 'thattes' in alternate tiers on the racks, leaving one tier empty between every two trays, atleast till the final moult. This will ensure better ventilation of the rearing beds and thereby, eliminate building up of excessive humidity over the bed. In this connection, it may be mentioned that sericulturists, in their anxiety to rear maximum number of layings within a limited space, tend to use racks with too many tiers, the space between them being 6" or even less. This does not permit of proper aeration of the rearing beds, particularly when the atmospheric humidity is high and also when the moisture content of the leaf is excessive. Hence, it is desirable that racks with atleast a minimum of 9" to 10" gap between the tiers are used. Further, where wooden trays are used for rearing, the height of the side walls should be about 3" only, so that there is sufficient gap available between any two successive trays.

In the cold season, the growth of mulberry is comparatively slower and so, the leaves also mature gradually. Such leaves have better keeping quality, optimum moisutre content and consequently better feed value. Four feeds per day may be found adequate and the leaves neither wither nor increase bed humidity, leading to normally successful crops, assisted also by favourable temperature/humidity conditions of the season as in December–January.

In seasons, when the day/night temperature difference is high *i.e.*, with a warm day and a cool to cold night, the leaf quality is again good, since the photosynthetic activity during day is maximum, while the assimilation of the manufactured food is minimum during night.

iv) Leaf Preservation:

It is important not only to produce highly nutritious and succulent leaves but also to preserve them after harvest in as fresh a state as possible till they are consumed by the silkworms. The freshly harvested succulent leaves undergo changes following harvest. The loss of moisture particularly is very rapid during hot dry seasons and this affects the edibility or palatability of the leaves for silkworms. In the multivoltine areas of India where the temperature is generally higher, the leaves wither fast and thus become nutritively poorer. To prevent withering of the leaves, attempts are made to increase and maintain the relative humidity of the rearing rooms. This step may be found only partially helpful in preventing quick withering, but is certainly detrimental to the health of the worms, particularly in the 4th and 5th stages, which are comparatively less resistant to high temperature and high humidity. Therefore, it is necessary to prevent moisture loss in leaves, at the same time, without increasing the humidity in the rearing rooms. This can be achieved in the following manner.

Fresh and succulent leaves harvested from the plant should be collected in wet gunny cloth or in bamboo baskets lined inside and covered with wet gunny cloth and

transported to the rearing houses where they should be immediately preserved loose under a wet cloth which should be kept sufficiently wet all the time by sprinkling water on it repeatedly at convenient intervals. Leaves preserved as above, in fact absorb more moisture and remain fresh for a longer time in the rearing beds and the worms eat them avidly. It has also been established that leaves so preserved, in fact, show higher moisture and protein content and that the higher moisture content helps digestibility of the worms. The direct result of such leaf preservation is much higher consumption by the worms and highly significant gain in weight of the worms. Therefore, proper preservation of moisture and other nutrients is essential and should be carried out without fail. Special leaf preservation bins covered with gunny cloth may be found useful for the purpose as shown in Figure – 1.

Figure 1 — Leaf storage bin being sprayed with water repeatedly during summer months

Sericulturists have the unfounded fear that such leaves may lead to Grasserie afflictions. On the other hand, it is the sprinkling of water in the rearing rooms with a view to raise humidity for the prevention of leaf withering that leads to unfavourable

atmospheric conditions in the rearing rooms and often results in outbreak of diseases. It should be remembered that the worms that are fed with such water treated leaves during preservation should be adequately spaced so that there may be proper ventilation in the rearing beds. Care should also be taken to see that directly wet leaves carrying water droplets over them are strictly avoided as this would lead to troubles from diseases. If any water droplets are found on the leaves they should be wiped out before being fed.

In rainy seasons, however, a situation quite opposite of what exists during hot weather prevails where the leaves contain more moisture and the atmospheric humidity is also generally high. At that time, the problem is not of leaf moisture preservation, but that of removing excess moisture present. The leaves harvested during rains normally keep well without withering much. Besides, they may also be wet and physically carrying droplets of rain water. Therefore, such leaves should be spread out thinly on the floor to drive out the excess moisture present on the surface of leaves and later heaped or stored in leaf bins. Sprinkling water for preservation may not be found necessary.

It may be found a convenient practice to pluck or harvest leaves twice a day. The first harvest should be made early in the morning and used to give the second feeding of the day, after the morning cleaning of the beds and again, the next one or two feeds in the afternoon. The second harvest of leaves should be made towards the evening and used for giving the night feed and also the early morning feed, the next day. Under this practice the leaves can be properly preserved and utilised.

v) Spacing of worms in the beds:

This is another important aspect to which great care and attention should be given. Till recently, the traditional practice has been to rear the worms very much crowded and this does not permit of free and complete growth of the worms. Despite all the care given to feeding of the worms by providing adequate quantities of leaves in repeated feedings etc., crowded conditions lead to under-nourishment and uneven development of the worms in the bed. The worms attain only restricted growth and become weak and easily susceptible to disease and other adverse factors. This results in comparatively poorer harvests and reduced average cocoon weight. According to the traditional practice, the worms from 100 disease free layings when fully mature are reared in about 10–12 bamboo circular trays of 4–4$^{1}/_{2}$' diameter and this spacing is far too inadequate. For obtaining best results of growth of worms, the following spacing should be adopted for the different instars in their various stages of development. The spacing indicated below is for 100 disease free layings with an average of 400 eggs per laying.

Schedule of Spacing (A)

Age of worms	Area required for rearing		Increase in spacing during each instar
	To begin with	At the end	
1st Instar	4 sq. ft.	14 sq. ft.	3 1/2 times
2nd "	15 "	45 "	3 "
3rd "	45 "	90 "	2 "
4th "	90 "	180 "	2 "
5th "	180 "	360 "	2 "

The above in terms of bamboo trays may be stated as follows:

Schedule of Spacing (B)

Age of worms	Trays of 3 1/2' diameter		Trays of 4' diameter		Trays of 4 1/2' diameter	
	Trays	Area of seat in each tray	Trays	Area of seat in each tray	Trays	Area of seat in each tray
1st Instar						
Brush in:	2	1 1/2' × 1 1/2'	2	1 1/2' × 1 1/2	1	2' × 2'
Increase to:	2	2 1/2' × 3'	2	2 1/2' × 3'	1	3 1/2' × 4' (or to fill almost the entire tray)
2nd Instar						
Increase from:	2	2 1/2' × 3' (or to fill almost the entire tray)	2	2' × 3 1/2'	1	"
to:	5	"	4	3' × 3 3/4'	3	"
3rd Instar						
Increase from:	5	Full Tray	4	3' × 3 3/4'	3	"
to:	10	"	8	Full Tray	6	"
4th Instar						
Increase from:	10	"	8	"	6	"
to:	20	"	15	"	12	"
5th Instar						
Increase from:	20	"	15	"	12	"
to:	40	"	30	"	25	"

The spacing as indicated above allows for maximum growth of worms and the worms in the bed also get proper aeration and plentiful supply of leaf feed (Figure–2). They grow vigorously attaining a weight of 4 to 5 gms. each and can resist disease and adverse climatic conditions. Further, correct spacing combined with the correct quantity of leaf to be fed (as indicated later in this bulletin) for each of the instars will help in the proper maintenance of rearing bed humidity and will lead to fuller utilisation of the leaf feed.

Figure 2—Spacing of Late Age Silkworms in the Rearing Bed.
A. Overcrowded with restricted worm growth
B. Optimum with maximum worm growth

As pointed out earlier, these norms of spacing, relate to layings where the average number of eggs is roughly about 400 in a laying and will vary correspondingly if the average number of eggs varies widely..

vi) Quantity of leaf to be fed :

If the suggestions mentioned above are systematically followed, it will not be necessary to give more than 4 to 5 feedings a day, whereas the traditional practice

has been to give 6 to 8 feedings a day. Again, according to the traditional practice, in view of the fewer number of trays used in rearing and the resultant crowded rearings, only about 400–500 kgs. of leaves are utilised to feed about 100 disease free layings. This quantity is far too inadequate and does not permit of maximum growth of worms. The reduced spacing and the consequent reduced leaf feed are mainly responsible for the poor cocoon harvests in the case of traditional rearing practices. Therefore, correct spacing and optimum quantity of leaf feed to be given, are vital factors to be kept in mind.

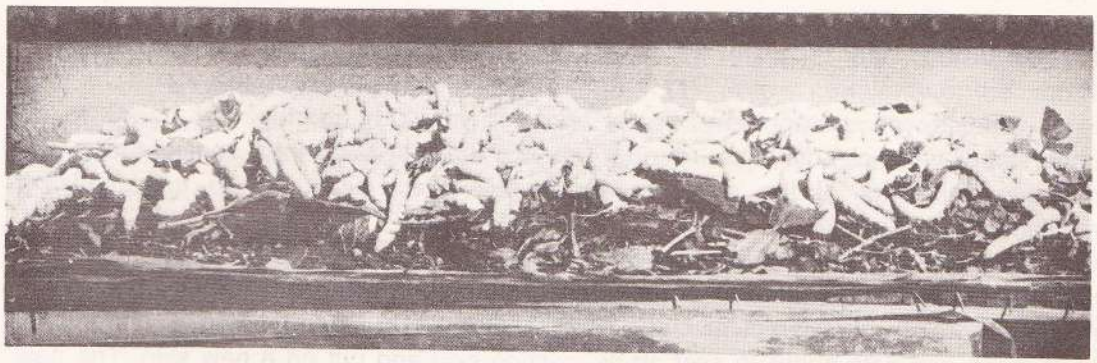
In this connection, experimental studies have established that the optimum requirement of leaf to rear 100 disease free layings (containing roughly 40,000 eggs) will be as follows in the different instars:

Age of the worm	Quantity of leaf to be fed	
	Multivoltine × New Bivoltine hybrid	Bivoltine × Bivoltine hybrid
1st instar	2– 2.5 Kgs.	2.5– 3 Kgs.
2nd instar	6– 7.0 "	8.0– 9 "
3rd instar	25– 30.0 "	35.0– 45 "
4th instar	75– 85.0 "	105.0–125 "
5th instar	600–625.0 "	700.0–725 "
Total	708–749.5 "	850.5–907 "
or say	700–750.0 "	850.0–900 "

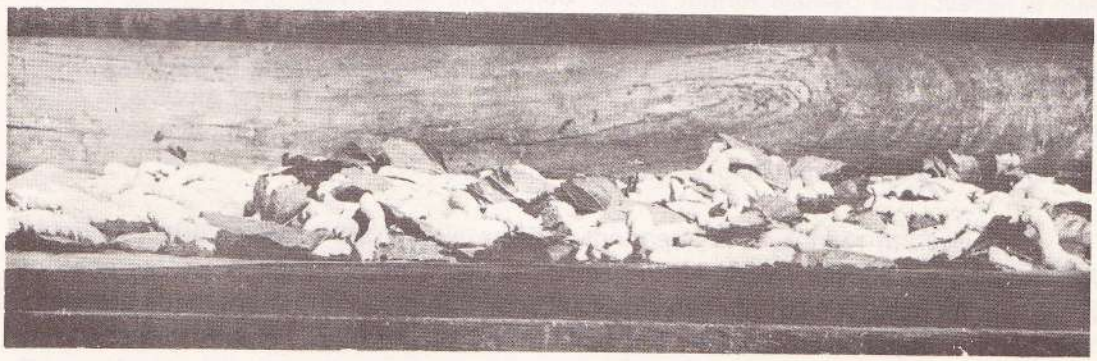
Thus, it is seen that doubling of spacing under improved technique of rearing also leads to increased consumption of leaves. These norms of leaf quantity to be used for feeding may have to be adjusted according to the average number of eggs in the layings, increasing the quantity when the number of eggs is more and reducing it when it is less than 400, as in the case of spacing already referred to earlier.

Also slight deviation from the above norms will become inevitable according to the prevailing seasonal conditions. During hot summer months, the leaves wither fast and therefore, besides an extra feed that may be found necessary, slightly increased feeding of leaves at every feed is desirable to build up necessary humidity in the bed. This may lead to an increase in leaf consumption by about 25 to 30 per cent. On the other hand, in the wet rainy season, the bed life of the leaf is longer and further, there is need to reduce the bed humidity which builds up rapidly due to higher moisture content in the leaves in that season. Therefore, the number of feeds to be given in a day could be reduced to four and again the quantity to be fed at each feeding could also be reduced. This will result in an overall reduction in the quantity of leaf to be fed by about 20–25%.

The recommendations made above in regard to spacing and quantity of leaf to be used for feeding will avoid, to a large extent, the unhealthy practice of building up rearing beds of 2"to 3" and over in thickness, which results from reduced spacing and overfeeding, as followed in the case of traditional rearings. Such thick beds may not harm the rearings during hot and dry seasons as in summer, but are highly detrimental to rearing in other seasons, as they build up bed humidity beyond tolerance limit and favour disease outbreak. Under the new technique recommended in this bulletin, the bed thickness is never allowed to build up more than half to one inch. As the worms grow in size and the leaf used for feeding also increases in quantity, the quantitatively mounting leaf feed is spread more in the horizontal direction by increasing the area of the rearing bed without allowing any significant increase in thickness. This helps to keep the bed humidity under control and to dry the bed easily when required. These are illustrated in the Figure–3.



A



B

Figure 3—Thickness of the Rearing Bed

A. Traditional Method–2" to 3" thick bed–More Humidity–More wastage of leaf
B. New Method–1" thick bed–Humidity under control– Better Utilisation of Leaf.

It is also a good practice, if the leaf bed in the tray is given a turning after 2–3 hours of feeding so as to expose the leaves unconsumed by the worms, which are still fresh at the bottom, for feeding again. This will ensure more effective utilisation of the leaf feed. Besides, during rainy season, it will help in driving out the excessive moisture building up in the bed.

In this connection, it may be emphasised that the secret of success in silkworm rearing lies in proper manipulation of quality of leaf and the quantity of leaf feed, so as to maintain the required humidity in the rearing bed. In other words, the leaf quality and quantity fed should be such that they prevent fast withering in summer leading to underfeeding and also building up of too much humidity in rainy season, which favours disease outbreak. In short, it may be summed up by saying that the success of rearing depends on **proper moisture management of the rearing bed.**

Thus, it may be seen that in the case of tropical sericulture, the rearing procedure is not the same or rigid as to be applicable uniformly in all seasons of the year. It needs to be suitably altered according to the differing seasons of the year and the consequent needs of rearing. This should be properly understood and fully appreciated.

vii) Moulting:

This is yet another very critical factor in silkworm rearing that needs to be understood very clearly. The rearing practice should take into consideration the moulting behaviour of the silkworm and handle them according to the needs of moulting.

The silkworm moults four times during its larval growth phase. After attaining the maximum growth in a particular stage or instar, the worm stops feeding, anchors itself to its base and sets about to cast off its existing skin and put on a new skin. The new skin in elastic and permits further growth during the next instar. It is thin and delicate in the begining and gradually hardens as the worm starts feeding following moulting and grows in size. Initiation of moulting and completion of the same takes place under dry conditions. The moulting takes about 20 hours in the case of first moult and about 30 hours for the final moult, while the intervening second and third moults take about 24 hours. During the moulting period, the worms do not eat.

In silkworm rearing, it is important that the worms are made to moult uniformly for ensuring successful crops. As the worms show signs of moulting and as soon as a few worms have settled, attention should be paid to the drying of the beds gradually. The paraffin paper used to cover the beds in the early stages should be removed to facilitate drying of the bed. If necessary, the rearing seat should be opened up and further spread out so that the beds may dry. As the bed becomes dry, more and more worms will settle. However, the few worms found still eating, should be continued to be fed with gradually reducing quantities of leaf for the next one or two feeds, by which time almost 100 per cent of worms would settle. As per the recommendations made under this new technique, the worms normally settle in about 6–8 hours from the time the first signs of moulting are noticed. However, it is important to remember that feeding should stop when about 90–95 per cent of worms have settled and not carried on till the moulted worms come out, simply because a few worms have not settled down.

While the worms are in moult, they should not be disturbed at all. Some people do the cleaning after part of the worms have already settled which is not correct. In fact, moulting time should be anticipated and the cleaning etc. carried out in time prior to the moulting. Again, the worms in moult should not be transported, from place to place over distances. "**chawki**" worms should always be transported when they are in the active feeding stage and in cool hours of the day. During moulting, the rearing rooms should be kept fully ventilated so that drying of rearing beds is facilitated.

Resumption of feeding should be done only after more than 90 per cent of the worms have come out of moult. As in the case of settling, most of the worms (over 90%) come out of moult within six to eight hours from the time the early moulted worms appear in the bed. After the worms have come out, they become active once again and are restive, hankering for food. At that time, they should be fed with fresh leaves over cleaning nets. Quite often, when moulting is prolonged due to irregular settling, resulting from non-observance of correct methods, the resuming feed is also delayed very much, so that all the worms may come out. In this process, majority of the worms which have come out already are denied their timely feed for the sake of a very small number of worms still to come out, resulting in most of the moulted worms being starved. This should be strictly avoided.

It is likely that some of the unmoulted worms also come up alongwith the resumption of feed for the next instar. Such worms should be systematically picked and rejected during the course of one or two feedings following the first net cleaning.

The freshly moulted silkworm is slow in eating and therefore, the first feed should be small and should contain chopped leaves of slightly tender quality. After two to three feeds, the worms start eating well, as they grow more and more in size. According to these habits, leaf feeds should also be regulated—feeding smaller quantities immediately after moulting and gradually raising it, as the eating rate increases.

viii) Growth of Silkworms:

Silkworms show fantastic rate of growth, gaining in weight about 10,000 times between hatching and final spinning of cocoons in a matter of about 24 to 25 days. The spacing of the rearing bed as well as the quantity of feeds given will have to be regulated to allow for this fast rate of growth, which will ensure full development of the larva throughout its larval period—right from the first instar to the fifth instar. The worm would then show about maximum growth, attaining a weight of 4 to 5 gms. Such worms will be healthy and will not fall easy prey to diseases. Further, they will produce cocoons of 1·75 to 2·0 gms and above in weight.

Under the ideal conditions required for best growth of silkworms, the larval development takes place over 24 to 26 days as indicated below:

Hatching	— 1st instar	3 to 3½ days	— 1st moult	— 20 hours.
	2nd instar	2½ to 3 days	— 2nd moult	— 24 hours.
	3rd instar	3 to 3½ days	— 3rd moult	— 24 hours.
	4th instar	4 to 4½ days	— 4th moult	— 30 hours.
	5th instar	6 to 7 days	— spinning	
		Total 23–26 days.		
		Average 24–25 days.		

There may be slight variations in the duration of different instars depending on the prevailing weather conditions, being slightly prolonged when atmospheric temperature is lower. Even in cold weather, if the rooms are warmed upto the optimum temperature required, the worm will undergo moult as per the schedule indicated above, indicating that maximum growth is taking place at every instar during its larval life. Inspite of the warmer weather, if there is delay in moulting, it would indicate that the rate of growth of the worm is slower, which may result from underfeeding or starvation that may be taking place due to overcrowding of the worms or the leaf feed drying fast and not being available as feed for the entire period between any two feedings. Starvation or underfeeding of worms leads to poor growth and weakening of the worms, which will ultimately become easily susceptible to diseases. If the larval period during these different instars gets prolonged, it is a clear indication that all is not well with the rearing. Therefore, it should be the endeavour to see that the first three instars are passed in 11 to 12 days, which will ensure good health and vigorous growth in the later stages.

III. IMPROVED TECHNIQUE

Based on the above considerations, the improved technique of silkworm rearing should be followed as indicated below.

i) Disinfection:

The rearing house as well as the appliances used in rearing should be invariably disinfected with 2% formalin prior to commencement of every rearing. This will be possible only when there is no overlapping in rearing. It is advisable to take larger rearings, one after the other, rather than having small rearings overlapping one another. Disinfection will prevent possible disease infection from the previous silkworm crops through the source of rearing debris present in the rearing house and the rearing appliances. For effective disinfection, the rearing house should be made air-tight as far

as possible and with the rearing appliances kept inside, the walls, windows, doors and the appliances should be sprayed with 2% formalin solution at the rate of 7–8 litres per 100 sq. metre and the doors closed immediately. After about 24 hours of disinfection, the doors and windows should be opened and the rearing house completely aerated atleast 24 hours before the commencement of brushing. If the rearing has suffered due to disease in the previous crop, the disinfection should be carried out with a higher concentration upto 4% for atleast 48 hours. In the case of the dwelling house, where in a part of the house silkworm rearing is carried out, the space and appliances used for rearing should be disinfected by spraying with a solution of formalin at 4%. If, there had been an occurrence of disease in the previous crop, a second spraying may also be given after a gap of 2–3 days, to ensure proper disinfection of the rearing space and appliances.

The formalin used should be strong, which is normally available as 40% strong solution in the market. If the formalin is not kept in suitable containers properly sealed, the formaldehyde gas will escape and the solution will fall in strength. 2% solution is prepared by diluting one part of 40% strong formalin with 19 parts of water.

ii) Quality of Eggs, Incubation and Hatching:

In addition to the suggestions made here regarding the rearing practices, it is also important that good quality eggs are secured from reliable sources so that good cocoon harvest could be reaped. Further, in order to facilitate easy and systematic rearing it is desirable that over 90% to 95% hatching at a time is achieved while brushing. Quality eggs from Government sources or grainages should be transported with due care, *i.e.*, without exposing them to adverse climatic conditions, particularly high temperature and low humidity.

Later, they should be incubated at a cool place by spreading out the egg cards on trays in single layers and covering them with paper. If the atmospheric relative humidity is below 70%, the humidity should be raised by placing wet foam rubber bands allround the egg sheets in the tray. The ideal temperature and humidity conditions for egg incubation should be around 25°C and 80% respectively. It is particularly important to see that the relative humidity of incubation is kept around 80% so as to avoid possible desiccation of the eggs.

Under the ideal temperature and humidity, the development of the embryo takes place steadily and uniformly. Even under fluctuating temperature, within reasonable range between 23°C and 28°C, the development of the embryo will be uniform and satisfactory. However, in order to get uniform hatching at the time of brushing operations, it is useful to put them in a dark atmosphere in a blackened box, roughly about 24 to 48 hours before the expected time of hatching, as indicated by the pin head stage of embryo development or the blueing of the egg. This will enable practically all the developing embroys to attain full and uniform growth without hatching. These black

boxed eggs, when exposed suddenly to bright light between 8 a.m. and 9 a.m. on the day of hatching, will ensure over 90 to 95% hatching in about one to two hours. Immediately after hatching, the worms should be fed and brushed on to the rearing tray. In this connection, it must be stressed that the worms should not be starved for unduly long periods, which will result in the worms getting weakened due to starvation.

iii) Rearing of Young Age Silkworms:

The success of silkworm rearing depends to a large extent on the successful rearing of young worms. The young larva of the silkworms shows vigorous growth at a temperature around 27°C and a relative humidity of 80 to 90%. Under these ecological conditions, they complete their growth in the minimum period. Such vigorously growing worms are healthier and more resistant to adverse climatic factors and disease in the late ages, thereby ensuring success of the cocoon crop.

Therefore, the rearing of the young silkworms must be carried out diligently. At the time of brushing, suitable tender leaves should be chopped into 0·5 to 1 cm. squares and sprinkled over the egg sheet of the hatching worms. After the worms have crawled on to the leaves they should be gently brushed on to the tray prepared for rearing the young age worms. In order to prevent drying of the chopped leaves, the rearing of the first two instars should be conducted in between paraffin paper sheets. If the atmospheric temperature is high and the humidity is low, it may be necessary to even provide wet paper or foam rubber bands allround the rearing bed in between the paraffin sheets as shown in Figure-4.

As an additional precaution to prevent drying of cut leaves, the trays could be piled up one over the other to a convenient height (upto 10–15 trays) as shown in Figure–5.

If, however, the relative humidity is over 90–95%, as it would be during heavy rains, and if the leaves happen to have excess moisture, it may be necessary to do away with the wet paper or foam rubber bands and even resort to the removal of the paraffin paper at the bottom of the rearing bed.

The intention in all these manipulations is to ensure that the rearing beds are not allowed to dry more than the optimum required or to remain too moist as to hamper the health of the young age worms. Experience has shown that it is in this important technical task that proper attention is not being given. This mainly leads to problems of disease at later stages.

During the first three instars, care should be taken to start with **tender** leaves that have reached normal size (*i.e.* top-most full blown leaf) and somewhat dark green in colour, for feeding the newly hatched worms. As the young age worms continue to grow, more mature leaves should be fed to them. The size of the chopped leaves

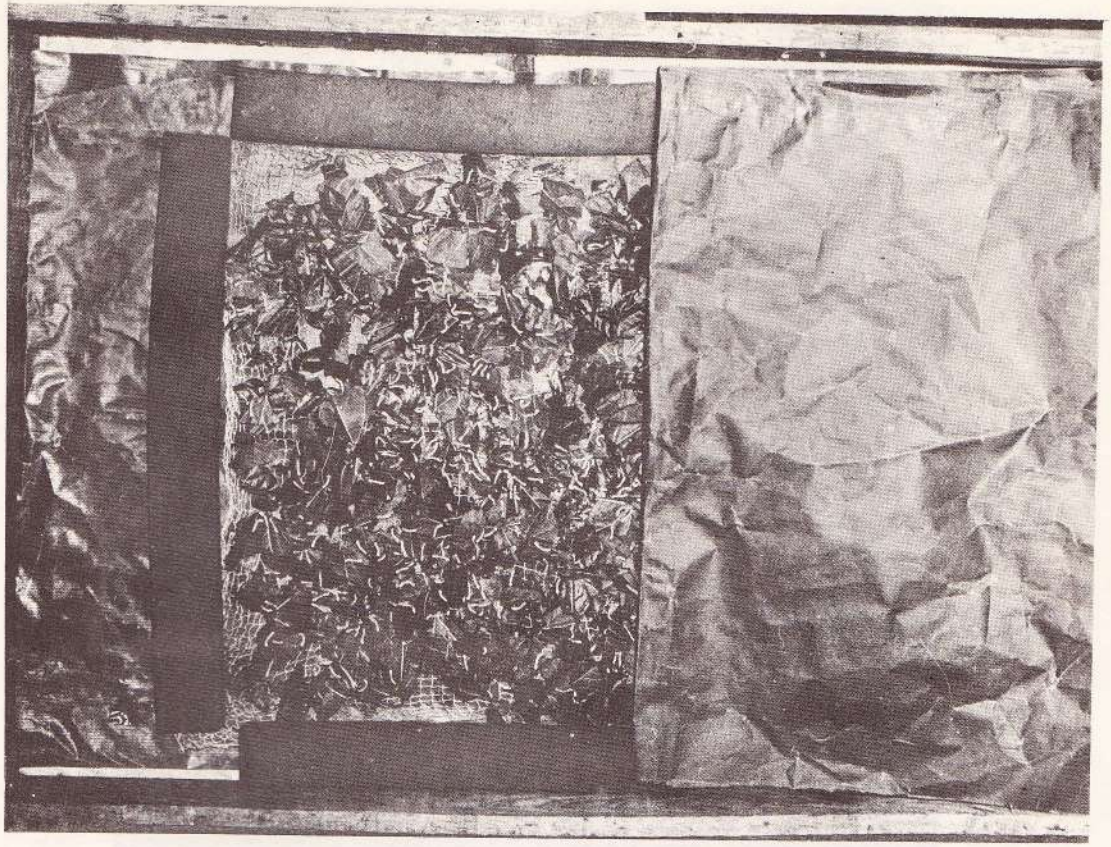


Figure 4—Rearing of young age worms between paraffin papers—provided with foam rubber bands allround the rearing bed.

should also gradually increase from 0·5–1 cm. to 6 cm. squares by the time they reach the end of the third age. When a feed is due, the paraffin paper covering the rearing bed should be removed atleast half an hour before the actual feeding so that uneaten leaves, alongwith the rearing bed itself, may completely dry before the fresh feed is given. Immediately after giving the chopped leaf, the rearing bed should be covered with the paraffin paper. Under our climatic conditions it is found that during wet weather the wilting of the leaves takes a longer time due to the high humidity. According to the climatic changes, we need to manipulate the rearing operations to ensure that the leaves do not dry quickly in dry periods and do not remain over-moist for unduly long periods during rainy seasons.

Figure 5 –Piling up of the chawki rearing trays—an additional precaution to prevent drying of cut leaves.

The early age larvae can be best reared in trays measuring 2′ × 3′ and $2^1/_2$″ - 3″ in height. Upto 10–15 disease free layings can be brushed in a tray of this measurement from hatching till the second moult.

The first age worms settle for moult within 3 - $3^1/_2$ days and in another 20 hours they will enter the second age. The second age is passed within $2^1/_2$ - 3 days and after 20–24 hours of moulting, they will enter the third age.

The third age worms coming out of the second moult are removed to round bamboo trays. During the third age, the humidity in the bed should be slightly lower and for this, the silkworms need to be reared only under the paraffin paper cover, but without any paraffin paper at the base. It is also no longer necessary to have any wet paper pads. The third age will take 3 to $3^1/_2$ days to settle for the third moult and in one day come out of the moult to enter the fourth age. Thus, the total period taken for the young age rearing lasts from 11 to 12 days.

The number of feeds to be given during the young age is three to four between 6 a.m. and 9 p.m. which may be at 6 a.m., 1 p.m., and 8 p.m. or at 6 a.m., 11 a.m., 3 p.m:, and 8 p.m. during the summer months. Bed cleaning will have to be done once in the first age prior to settling for moulting, twice during the second stage, *i.e.* first after first two feeds, and again prior to settling for second moult, and three times in case of third age worms, *i.e.* once after two feedings after moulting, second after two days and third just prior to settling for third moult. These operations can be summarised as shown in the table below:

Rearing Schedule of Young Age Silkworms
(For 100 Disease free layings)

Age of Silkworm	Temperature °C	Humidity %	Size of Leaves (cms.)	Total quantity of leaf (kgs.)	No. of feeds/day	No. of cleaning/ instar	Spacing (Reaing seat for 100 dfls) (sq. ft.)
Improved Multivoltine Hybrids							
I	27	80–90	0·5 to 2·0	2 to 2·5	3 to 4	1	4 to 14
II	27	80–90	2·0 to 4·0	6 to 7·0	3 to 4	2	15 to 45
III	26	80	4·0 to 6·0	25 to 30	4 to 5	3	45 to 90
Bivoltine Hybrids							
I	27	80–90	0·5 to 2·0	2·5 to 3	3 to 4	1	4 to 14
II	27	80–90	2·0 to 4·0	8 to 9	3 to 4	2	15 to 45
III	26	80	4·0 to 6·0	35 to 45	4 to 5	3	45 to 90

(iv) Rearing of Late Age Silkworms:

The fourth and fifth instars of the silkworms are somewhat more delicate and therefore, need more rigid conditions of temperature and humidity. They normally thrive well under comparatively lower temperature and are sensitive to high temperature and humidity conditions. Under high humidity conditions as in rainy days, more ventilation and greater spacing should be resorted to, and all care should be taken not to over feed the worms, as it would lead to bed thickening resulting in wet beds. It may also be found advisable to chop the leaves during the rainy days, although under normal conditions, the entire leaf could be fed to the fourth and fifth age worms. For these late age worms, more mature leaves which contain less of moisture in them should be given. As already mentioned earlier, during dry days all attention must be focussed on the proper preservation of leaves, as the health of the worms depends very much on the quality and quantity of leaves consumed. If the leaf is not sufficiently fresh, its edible quality is reduced and the worms tend to go under starvation inspite of the presence of leaves in the trays.

The late age worms of fourth and fifth instars are real feeding stages consuming about 90 to 95 per cent of the total feed and therefore, adequate spacing and adequate amount of feed should be given at these two ages. The worms in the fourth and fifth ages need be given only four feedings at 6 a.m., 11 a.m., 3 p.m. and 9 p.m. and during hot months five feedings at 6 a.m., 10 a.m., 2 p.m., 6 p.m. and 10 p.m. It would be advisable to give a fairly large feed at night.

When the worms are reared on trays, it would be necessary to give bed cleaning once in the morning every day. The operation connected with the rearing of the late age worms can be summarised as shown in the table below.

Rearing Schedule of Late Age Silkworms
(For 100 Disease free layings)

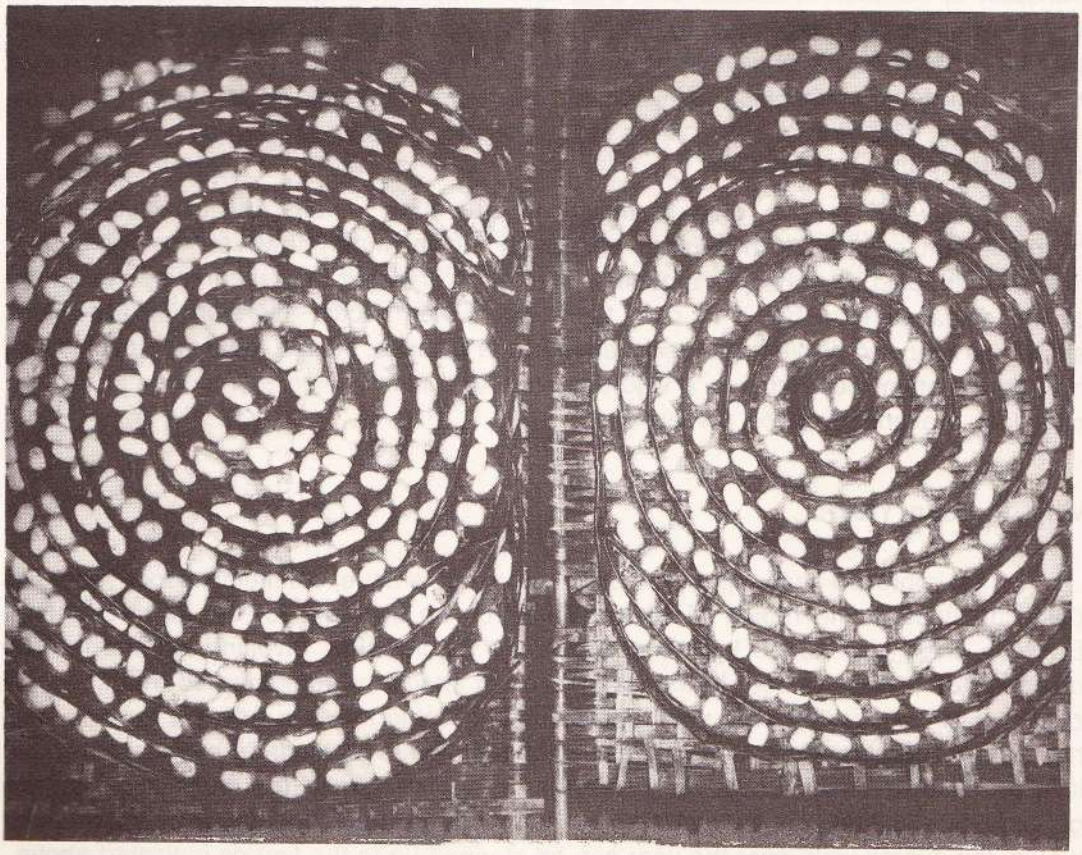
Age of Silkworm	Temperature °	Humidity %	Size of Leaves (cms.)	Total quantity of leaf (kgs.)	No. of feeds/day	No. of cleaning/ instar	Spacing (Rearing seat for 100 dfls) (sq. ft.)
Improved Multivoltine Hybrids							
IV	Atmospheric Temperature	70–75	Entire Leaf	75–85	4–5	Once in the morning daily	90–180
V	"	70	Entire leaf or branches	600–625	4–5	Daily	180–360
Bivoltine Hybrids							
IV	"	70–75	Entire leaf	105–125	4–5	Once in the morning daily.	90–180
V	"	70	Entire leaf or branches	700–725	4–5	Daily	180–360

Note: Ensure circulation of air if too warm and humid

v) Mounting:

On the completion of full 6 or 7 days after passing the fourth moult, the worms will cease feeding and become ripe for mounting. Ripe worms should be picked in time so that all the maturing worms are enabled to spin cocoons successfully. Worms not picked in time or unduly delayed in picking can also be mistaken for diseased worms. Similarly, worms picked much before ripening, may not also spin resulting in unnecessary crop losses at the last stage of rearings. Therefore, it is important that maturing worms as they show signs of maturity (from the transluscent body colour and the active raising of heads by the ripe worms) should be picked in time and mounted to get full benefits of successful rearings.

Under the improved methods of rearing suggested here, the worms will grow uniformly and therefore, will also mount uniformly completing mounting within the shortest possible time. Majority of the worms will mount in 24 hours and the total time taken for all the worms to mount will not exceed 2 days.



Figure–6 —Density of Mounting

A. Overcrowded
(leading to double cocoon formation)

B. Normal
(40–45 cocoons per sq. ft.)

Mounting of worms on the chandrikes is another very important point to which sufficient attention should be paid. Mounting should be done in well ventilated rooms or in shade in the open to facilitate undisturbed spinning. The ripe worms must be mounted at the rate of 40–45 worms per sq. ft., so that formation of double cocoons may be avoided (Figure–6). Under crowded mounting, the percentage of double cocoons rises significiantly. This will bring down the over-all quality of the harvest, resulting in higher renditta for the lot. As a consequence, the price fetched will be lower.

vi) Harvest:

Spinning of cocoons by the worms takes place over two or three days and thereafter, the spun worms turn into pupae by the next day. Therefore, it is important that the cocoon harvest is delayed till the sixth day *i.e.*, after completion of full five days reckoning from the last day of mounting. By this time, all the worms would have formed into pupae and the cocoon shell will also have dried sufficiently to stand well the transport of cocoons in bulked lots. Otherwise, they will run the risk of being crushed or heated up due to excessive moisture present, leading to lowering of the quality and consequently to lower price for the cocoons in the markets. In the rainy season and in the cold weather the harvesting should be delayed further by a day more.

vii) Mortality due to Diseases:

In silkworm rearing, disease afflictions are rather serious and this subject will be dealt with separately in another bulletin of the Institute. However, for combating diseases, it could be stated as a general rule that it is easier to prevent the occurrence of the diseases than trying to cure them when they occur. Therefore, every effort should be made to prevent the occurrence of the disease. All the measures discussed here to maintain the worms in a vigorous state of health will go a long way in almost complete prevention of the diseases.

viii) Cocoon Yield:

The improved technique discussed here will ensure optimum cocoon harvests being obtained in the region of 40 to 45 kgs. on an average, for the Mysore × New Bivoltine cross and 45–50 kgs. on an average for the New Bivoltine hybrids for 100 disease free layings reared. In this connection, it should be remembered that seasonal conditions influence the crop yields considerably, being lower in adverse summer and higher in favourable winter seasons, which is common to all kinds of hybrids. However, it is possible to obtain about 35 to 40 kgs. in summer while the same in winter will go upto 50–55 kgs. on an average by adopting the improved techniques. In other words, the overall yield over the year can be stepped up to the figures indicated above.

In the case of rainfed mulberry, the yields will be comparatively lower, but all the same it will be in the region of 30–40 kgs. for 100 disease free layings on an average.

IV. ADVANTAGES

A comparison of the improved technique of rearing with the conventional method of rearing will show clearly that under the improved technique, the leaf produced is most efficiently utilised since the leaf cocoon ratio works out to be 15–20:1 as against 20–25:1 or even more in the case of conventional method of rearing. Further, for producing the same quantity of cocoon crop, the seed required is just half. Also the cocoon produced is of such superior quality that a premium price of 30 to 50 per cent more can be easily obtained in the cocoon markets for the cocoons obtained in the improved technique of rearing. Thus, the new technique helps the sericulturists to obtain both higher yields as well as higher prices for the cocoons produced.

It may also be mentioned in this connection that the sericulturists used to lose on an average one crop out of every three or four crops and crop failures are regular features under the conventional method of rearing, whereas in the case of improved technique, the crop failures are very rare and almost completely eliminated. Even if there were to be any disease infection, it does not result in the total loss of the crop and to a large extent the crop is saved. The crop is generally successful and the effective rate of rearing reaches 70–80% and above, and this mainly accounts for bumper harvests.

Thus, it may be seen that the adoption of the improved technique of rearing as recommended by the Institute is an essential step in sericulture practice which would ensure sustained production of bumper crops.