Standardization of Seed Production Technique of Muga Silkworm (*Antheraea assama* Westwood) in Terai Region of West Bengal

THESIS SUBMITTED TO

THE UNIVERSITY OF NORTH BENGAL
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
(SCIENCE)

By

INDRAJIT BISWAS

DEPARTMENT OF ZOOLOGY
UNIVERSITY OF NORTH BENGAL
RAJA RAMMOHUNPUR, DARJEELING

2008

Dedicated to

MY BELOVED SON

Dr. Nilay Ray
Head of the Department
Post Graduate Department of Zoology
&
Principal Investigator
Muga Research Laboratory
Acharya B.N. Seal College
Cooch Behar-736101
West Bengal, India

Phone : (03582) 226112 (O)
(03582) 250491 (R)
(+91) 9434081128
Fax : (03582) 228850
(03582) 250047
E-mail : watchnilay@gmail.com

Ref. No. ....

Date 4. 7. 2008

CERTIFICATE

This is to certify that the thesis titled **Standardization of Seed Production Technique of Muga Silkworm (*Antheraea assama* Westwood) in Terai Region of West Bengal** embodies the records of original investigation carried out by Mr. Indrajit Biswas, M.Sc. under my supervision. Mr. Biswas worked on this topic for about six years.

Mr. Biswas has fulfilled the requirements of the University of North Bengal for submission of his thesis. I am pleased to forward this thesis for submission to the University of North Bengal for consideration for the award of the degree of **Doctor of Philosophy** (Ph. D.) in Science (Zoology).

Nilay Ray. 4.7.2008

(NILAY RAY)
Lecturer (Sr. Scale) & Head
Post Graduate Department of Zoology
Acharya B.N. Seal College
Coochbehar.

ACKNOWLEDGEMENT

Scientific words are mainly based upon on experimental analysis depending on which the dream inference can be applied to the field and executing such experimental work a proper guidance in inevitable. So, it also happened with me. It's the generous and kind guidance, of Dr. Nilay Ray, Department of Zoology, Acharya B.N.Seal College, Cooch Behar, West Bengal, without which my research work would have been a mere dream. He provided me illuminate guidance, valuable suggestions, constructive criticisms, intensive encouragement, generous advice and endless co-operation through out my research work.

I am also grateful to the University Grants Commission, New Delhi for providing financial assistance through Major Research Project entitled "Improvement and standardization of seed (egg) production technology of Muga Silkworm Antheraea assama *Westwood in Terai region of West Bengal." implemented at Muga Research Laboratory (MRL), Acharya B.N.seal College, Cooch Behar, West Bengal.*

It is really great opportunity for me to pay tribute to all my teachers and elders who have constantly inspired me and imbibed in me the quest for knowledge. I express my gratitude to my parents and all my family members who laid down the foundation of my character. Their constant love and support gave me the self confidence to dream big.

I also express my sincere gratitude to the Principal, Acharya B. N. Seal College, Cooch Behar, West Bengal, for providing me with necessary facilities for the present investigation.

I like to express my grateful veneration and esteem to the Head and Teachers, Department of Zoology, Acharya B.N.Seal College, Coochbehar, West Bengal, for providing me the valuable suggestions as and when needed.

Sincere thanks are also extended to Atish Shamadhikari, Lab Assistant and Non-teaching staff of the Department of Zoology for their co-operation during my work.

I am greatfully acknowledge the Director, CSR & TI, Central Silk Board, Berhampore, RMRS, CBS, Ministry of Textile, Boko, Assam for necessary support and library facilities as and when required during the course of my investigation.

It is my proud privilege to maintain the immense help and support which I received from Sri. Supratim Das, Superintendent of Sericulture and Deputy Director-In-Charge Cooch Behar, West Bengal, for providing me valuable suggestion and various instructional field of muga culture when needed.

I also convey sincere gratitude and thanks to the Head and Teachers, Department of Zoology, University of North Bengal for their inspirational advice.

I am also grateful and should acknowledge to Prof. D.C. Deb (Ex-professor, Department of Zoology, N.B.U.) for his necessary suggestions.

Thanks also extended to Ph. D. Scholars namely Supriya, Uddalok, Samiron, Ujjal, Debasis da, Hiranmayananda, Tamal and Bikash for their help and constant inspiration during the course of my work.

Thanks are also due to Prasenjit, Deep, Dipankar, Partha Da, Abhijit Da, Rajib, Raja Da, Pradip Da and other senior mess members for their keen interest, support and co-operation during the course of my study.

Sincere thanks are also extended to Mr. Joy Bishnu and Mr. Sanjay Debnath for the arduous task of typing the manuscript.

Very Special thanks to my wife for her immense corporation through out my research work

Finally, I owe my encompassing debt to my parents for their silent blessing, along with moral support showered, which have always been source of my energy, inspiration and mental strength.

Dated: Cooch Behar,

the 7th July, 2008

Indrajit Biswas

(*INDRAJIT BISWAS*)

CONTENTS

Sl. No.		Page No.
CHAPTER-I		
1	**Introduction**	**1-10**
CHAPTER-II		
2	**Review of Literature**	**11-32**
2.1	Environmental effect on muga silkworm seed production	11
2.2	Effect of host plant on Seed production	17
2.3	Manipulation of abiotic factors for seed production	22
2.4	Synchronization of moth emergence and coupling for seed production	24
2.5	Characterization of Cocoon for selection of seed cocoon	27
2.6	Short-term cold preservation for seed production	29
CHAPTER-III		
3	**Materials and Methods**	**33-42**
3.1	Geographical location	33
3.2	Climate	34
3.3	Experimental Site	34
3.4	Insect	34
3.5	Food plants or host plants	35
3.6	Rearing of silkworm	35
3.7	Seasonal influence of grainage parameters of muga silkworm	35
3.8	Manipulation of abiotic factors	37
3.8.1	Manipulation of temperature	37
3.8.2	Manipulation of relative humidity (RH)	37
3.8.3	Manipulation of temperature and RH	37
3.8.4	Manipulation of temperature, humidity and photoperiod	37
3.9	Synchronization and Mating behaviour	37
3.9.1	Synchronization	37
3.9.1.1	Synchronization in normal condition	37
3.9.1.2	Synchronization by short-term cold preserved condition	38
3.9.2	Mating behaviour	39
3.9.2.1	Mating duration	39
3.9.2.2	Repeated mating	39
3.10	Characterizations of seed cocoons	39
3.11	Short term cold preservation of cocoon, moth and egg	40
3.11.1	Preservation of cocoons	40
3.11.2	Preservation of adults	41
3.11.3	Preservation of eggs	41
3.11.4	Continuous preservation cocoon, moth and egg	41
3.12	Statistical analysis	41

CHAPTER-IV

4	**Results**	**43-112**
4.1	Seasonal Influences on Grainage Performances of Muga Silkworm	43
4.1.1	Environmental factors during different seed production period of muga silkworm	43
4.1.1.1	Temperature during different seed production periods	43
4.1.1.2	Relative humidity during seed production period	44
4.1.1.3	Photoperiod during different seed productive period	45
4.1.1.4	Rainfall during different seed productive period	45
4.1.2	Intrinsic factors influencing seed production of muga silkworm fed on different host plants during different seasons	46
4.1.2.1	Pupal period	46
4.1.2.1.1	On Som plant	46
4.1.2.1.2	On Soalu plant	46
4.1.2.2	Emergence period	46
4.1.2.2.1	On Som plant	46
4.1.2.2.2	On Soalu plant	47
4.1.2.3	Mating period	48
4.1.2.3.1	On Som plant	48
4.1.2.3.2	On Soalu plant	48
4.1.2.4	Oviposition period	48
4.1.2.4.1	On Som plant	48
4.1.2.4.2	On Soalu plant	48
4.1.2.5	Incubation period	49
4.1.2.5.1	On Som plant	49
4.1.2.5.2	On Soalu plant	50
4.1.3	Seed production of muga silkworm fed on different host plants during different seasons	50
4.1.3.1	Potential fecundity	51
4.1.3.1.1	On Som plant	51
4.1.3.1.2	On Soalu plant	51
4.1.3.2	Realized fecundity	51
4.1.3.2.1	On Som plant	51
4.1.3.2.2	On Soalu plant	52
4.1.3.3	Egg Retention	52
4.1.3.3.1	On Som plant	52
4.1.3.3.2	On Soalu plant	53
4.1.3.4	Hatching percentage	53
4.1.3.4.1	On Som plant	53
4.1.3.4.2	On Soalu plant	54
4.1.4	Co-relation Studies	54
4.1.4.1	On Som plant	54
4.1.4.1.1	Environmental factors with intrinsic factors	54

4.1.4.1.2	Environmental factors with seed production parameters	55
4.1.4.1.3	Intrinsic factors with seed production parameters	55
4.1.4.2	On Soalu plant	56
4.1.4.2.1	Environmental factors with intrinsic factors	56
4.1.4.2.2	Environmental factors with seed production parameters	56
4.1.4.2.3	Intrinsic factors with seed production parameters	56
4.1.5	Seasonal influence on day wise egg laying and hatching	57
4.1.5.1	Effect of season on grainage parameters	57
4.1.5.2	Day wise seasonal egg laying and hatching	58
4.1.5.2.1	Egg laying	58
4.1.5.2.1.1	Seasonal influence	58
4.1.5.2.1.2	Day-wise effect	58
4.1.5.2.1.3	Effect of season & day	59
4.1.5.2.2	Hatching	59
4.1.5.2.2.1	Effect of season	59
4.1.5.2.2.2	Effect of day	59
4.1.5.2.2.3	Effect of season and day	60
4.1.5.3	Percentage of egg laying and hatching in different days	60
4.2	4.2. Manipulation of abiotic factors to standardize the optimum combination responsible for seed production with higher hatchability	61
4.2.1	Manipulation of Temperature	62
4.2.1.1	Manipulation of temperature during April – May	62
4.2.1.2	Manipulation of temperature during August – September	63
4.2.2	Manipulation of Relative humidity (RH)	63
4.2.2.1	Manipulation of RH during April-May	64
4.2.2.2	Manipulation of RH during August-September	64
4.2.3	Manipulation of temperature and relative humidity	65
4.2.3.1	During April-May	65
4.2.3.2	During August-September	65
4.2.3.3	Rate of embryonic development	66
4.2.4	Manipulation of temperature, humidity and photoperiod	68
4.2.4.1	During April-May	68
4.2.4.2	During August-September	69
4.3	Synchronization of male and female moth emergence and mating behaviour studies for quantitative improvement of quality seed production	71
4.3.1	Synchronization in normal condition	71
4.3.1.1	Coupling efficacy	71
4.3.1.1.1	During March-April	71
4.3.1.1.2	During September - October	71
4.3.1.2	Fecundity	73
4.3.1.2.1	During March-April	73
4.3.1.2.2	During September - October	74

4.3.1.3	Hatching percentage	75
4.3.1.3.1	During March April	75
4.3.1.3.2	During September - October	75
4.3.2	Short term cold preservation of moth for synchronized mating	77
4.3.2.1	Coupling efficacy	78
4.3.2.1.1	During March-April	78
4.3.2.1.2	During September - October	78
4.3.2.2	Fecundity	79
4.3.2.2.1	During March-April	79
4.3.2.2.2	During September - October	80
4.3.2.3	Hatchability	81
4.3.2.3.1	During March-April	81
4.3.2.3.2	During September - October	82
4.3.3	Repeated Mating	83
4.3.3.1	Effect of different mating hours on egg laying and hatching	83
4.3.3.2	Effect number of mating utilizing single male moth on egg laying and hatching	84
4.3.3.2.1	During March - April	84
4.3.3.2.1.1	Egg laying	84
4.3.3.2.1.2	Egg Retention	84
4.3.3.2.1.3	Hatching	85
4.3.3.2.2	During September – October	85
4.3.3.2.2.1	Egg laying	85
4.3.3.2.2.2	Egg retention	86
4.3.3.2.2.3	Egg hatching	86
4.4	Characterization of seed Cocoon	87
4.4.1	Preliminary Screening of seed cocoon	87
4.4.1.1	Screening on the basis of cocoon weight	87
4.4.1.2	Screening on the basis of cocoon length	88
4.4.1.3	Screening on the basis of cocoon width	88
4.4.1.4	Screening on the basis of cocoon weight, length and width	89
4.4.1.5	Co-relation Study	90
4.4.2	Sex-wise distribution pattern of different cocoon weight group	91
4.4.2.1	Distribution pattern of male cocoon	91
4.4.2.2	Distribution pattern of female cocoon	92
4.4.3	Relation between pupal weight and cocoon weight	92
4.4.3.1	Male cocoon weight corresponding male pupal weight	92
4.4.3.2	Female cocoon weight corresponding female pupal weight	92
4.4.3.3	Co-relation studies between cocoon weight and corresponding pupal weight	93
4.4.4	Fecundity, egg vigour and hatchability as influenced by different combinations of male and female cocoon	94
4.4.4.1	On Fecundity	94
4.4.4.2	On Hatchability	94

4.4.4.3	On Egg Weight	94
4.4.5	Female cocoon weight groups and influence on grain age parameters	96
4.4.5.1	On Fecundity	96
4.4.5.2	On egg vigour	97
4.4.5.3	On Hatchability	97
4.4.5.4	Co-relation studies	97
4.5	Short-term cold preservation of cocoon, moth and egg of muga silkworm	99
4.5.1	Muga silkworm survivability and egg production during adverse months	99
4.5.1.1	Effective Rate of Rearing	99
4.5.1.2	Realised fecundity	99
4.5.1.3	Hatchability	99
4.5.2	Preservation of cocoon	100
4.5.2.1	Pupal period	100
4.5.2.2	Emergence percentage	100
4.5.2.3	Coupling efficacy	100
4.5.2.4	Fecundity	102
4.5.2.5	Hatchability	103
4.5.3	preservation of adult	103
4.5.3.1	Coupling Efficacy	103
4.5.3.2	Fecundity	103
4.5.3.3	Hatching percentage	104
4.5.4	Preservation of egg	104
4.5.4.1	Incubation period	105
4.5.4.2	Delay of hatching	106
4.5.4.3	Hatching percentage	107
4.5.5	Continuous preservation of cocoon, adult and egg	108
4.5.5.1	Effect of cocoon preservation on adult emergence	108
4.5.5.1.1	Pupal period	108
4.5.5.1.2	Emergence Percentage	109
4.5.5.2	Effect of adult preservation on egg production	109
4.5.5.2.1	Coupling efficacy	110
4.5.5.2.2	Fecundity	110
4.5.5.2.3	Hatchability	110
4.5.5.3	Effect of egg preservation on hatchability	111
4.5.5.3.1	Incubation Period	111
4.5.5.3.2	Days delayed	112
4.5.5.3.3	Hatching Percentage	112
CHAPTER V		
5	**Discussion**	**113-135**
5.1	Seasonal Influences on Grainage Performances of Muga Silkworm	113
5.2	Manipulation of abiotic factors to standardize the optimum combination responsible for seed production with higher hatchability	118

5.3	Synchronization of male and female moth emergence and mating behaviour studies for quantitative improvement of quality seed production	121
5.4	Characterization of seed Cocoon	126
5.5	Short-term cold preservation of cocoon, moth and egg of muga silkworm	129
CHAPTER VI		
6.	**Summary**	**136-143**
CHAPTER VII		
7	**References**	**144**
8	**Publications related to this work**	**-**

CHAPTER - I

INTRODUCTION

Introduction

Silk is associated with mankind since 5000 years back. Although share of silk among world production of textile fibres is just 0.15%, it is appreciated for its unique qualities of texture so soft and smooth lustre, shine, graceful and sensuous, and elegance that place silk as the queen of textiles. The history of Indian silk is traced back to 1500 BC, as evidenced from the oldest known writing on silk in the epic Ramayana. India has the unique distinction of producing all the five varieties of silks of commerce viz. mulberry, oak tasar, tropical tasar, eri and muga (figure 1). India is the second largest producer of both the mulberry and tasar varieties of silk in the world with a share of 18% and 10% of the total respectively, while the golden yellow muga silk is produced only in India (Benchamin and Giridhar, 2005).

Table 1 World production of mulberry raw silk 1938 – 2003 (in tons)

Producer	1938	1978	1986	1997	2000	2003
Total of which	54675	45125	62460	79590	71163	117000
China	4855	19000	35700	55117	50683	94600
India	690	3475	8280	14048	15714	15472
Brazil	35	1250	1680	2120	1389	1563
Uzbekistan	1900	3240	4020	2000	1100	950
Thailand	NA	NA	NA	1039	955	1500
Japan	431150	15960	8220	1920	557	287
Rep of Korea	NA	NA	1680	146	15	150
Vietnam	NA	NA	NA	834	NA	750

Source: ISA, except for the year 2003 Central Silk Board

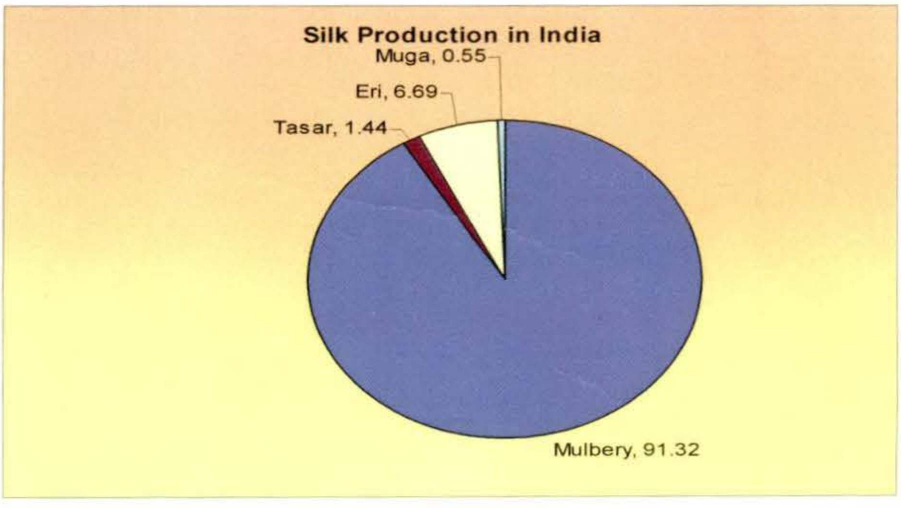

Figure 1 Silk production in India

Sericulture is not only the production of cocoons and silk for income generation, but has become the weft of the cultural fabric of the Asian countries in general and India in particular. Silk has a long tradition with pivotal role in Indian culture. It is a cottage industry spread over 53,184 villages in India, employing 5.8 million people, and it is potential tool for the improvement of economic conditions in rural area, involving the marginal and small farmers. Besides, sericulture has been accepted as a strong instrument of poverty alleviation and generation of rural employment for India, as 70% of the gross population of the country are rural and depend on land-based activities for their livelihood. Sericulture has also been considered as a women-friendly profitable enterprise ensuring the activity for socially deprived 50% women population of rural India. Considering the same, Govt. of India has rightly recognized its importance and included in the 10-point agenda of the common minimum programme of the centre.

The Indian sericulture industry has grown many folds since independence, *i.e.* from about measure 900 MT in 1950 to the present production level of about 19000 MT in 2007 (Table 2).

Table 2 Raw silk production-India (Unit: MT)

Variety	2003-2004	2004-2005	2005-2006	2006-2007
Mulberry	13,970	14,620	15,445	16,805
Tasar	315	322	308	325
Eri	1352	1448	1442	1515
Muga	105	110	110	115
Total	15,742	16,500	17,305	18,760

Source : Silk prices, *Indian silk*, vol. **46**(2), 2007 and vol. **44**(5), 2005.

This could be achieved due to the concerted research and development efforts of different institution of Central Silk Board, State owned institutions and different Universities. The breakthroughs made in past towards the evolution and release of improved host plant varieties as well as silkworm breeds together with the cultivation practices and rearing technologies led to the increase in silk production of better quality and sericulture could establish itself as the most remunerative enterprise. The technology and skill, which are within the reach of rural community, enables better and quick returns comparable to other cash crops besides frequent returns at regular intervals. All the four sectors of silk industry namely, egg production, silkworm rearing for cocoon production, silk reeling and weaving, printing and dying have been well established with modern technologies and other support services.

A very interesting development in the recent years is that of diversification of employment structure from agriculture to services in some parts of the country. In most of the agriculturally developed states, the share of agriculture in total employment in gradually declining. The employment in the manufacturing industries in organized sector is practically stagnant due to modernization and technological developments and increased capital investments. The service sector-trade, financial, community and personal services is, of course, recording a good growth as well as increase in employment, but here again, the imperative need to improve efficiency and productivity requires that more and better services be rendered by a much smaller increase in employment than in the earlier years.

By carrying industries to the countryside large-scale rural out-migration can be avoided. Sericulture based rural industrialization could stop skill drain from the countryside if sufficiently lucrative alternatives for employment are provided. These could be not only in the form of workers but also as owner-manager. Rural investible surplus could be absorbed directly in local income generation processes. Development and growth in agriculture has brought prosperity and wealth to rural people that should be utilized for creating climate conductive for setting up more sericulture based rural enterprises for meeting local needs.

This will also have a significant spin-off for agricultural development. By creating of better rural infrastructure, it could raise agricultural productivity through provision of better roads, canals, storage facilities, commerce, transport and communication facilities, etc. There would be increased availability and improved capacity for maintenance, repair and improvement of farm machinery. Further, this would also help in reduction of regional disparities through location of such units in backward areas. It would thus help in generation of new employment opportunities, creation of new skills and open up space for rural entrepreneurship.

United States of America (US Market) is the biggest importing and consuming country for silk and silk products in the world. The European consumers (EU market) are more respective to silk, silk products, and are most attracted towards fashionable high priced products (figure 2).

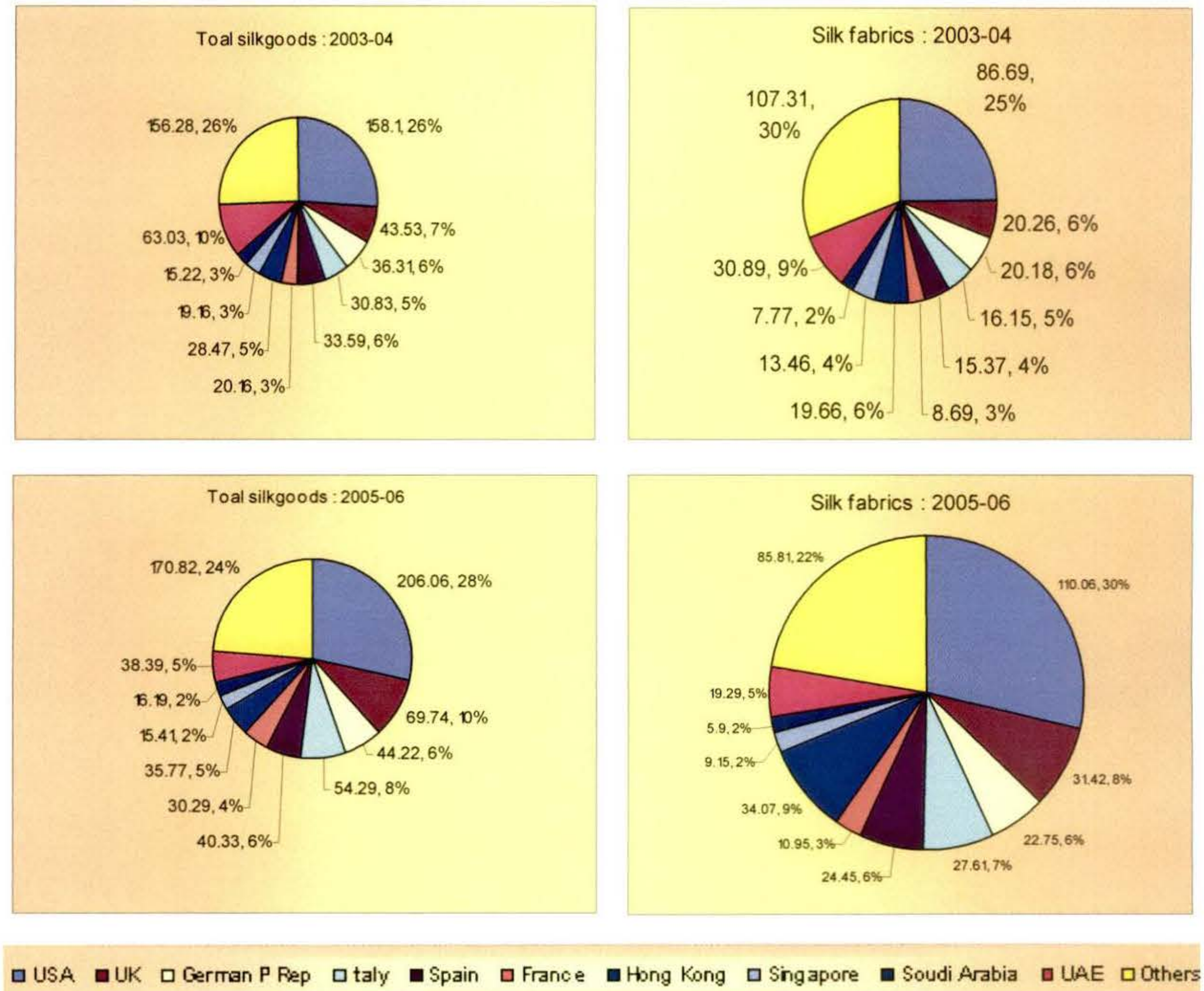

Figure 2 Country wise share of silk export from India (Mn US$ and %)

China and India remained the dominant producers of silk, together contributing more than 80% of the world raw silk. New countries like Brazil and Thailand though small are fast emerging as major silk suppliers to the world leading to increased competition.

There are new challenges amongst silk producing countries Market access has become more liberal and consequently, the competition is becoming tougher This is already happening in India *vis a vis* China. There is going to be more competition from other textiles competing with silk This is going to happen in several Asian silk producing countries where local consumers are targeted by this external competition.

In export markets, the situation is also going to change whilst the quotas were in place, silk products were generally given preferential status, but from 112005, the competition is tougher since the quotas are no more a limiting factor for other textiles. It is still a little early to estimate how the producing countries are reacting to the new trading situation.

One of the positive features in the silk trade is unlike the other textile fibres, there has always been a long tradition of using silk in all Asian silk producing countries India is consuming about 85% of the country's silk production and in some other countries, such as China and Vietnum, where silk consumption temporarily decreased; one can expect a strong increase in silk consumption when the purchase power of local consumers continues to grow. As is usual in export trade, one can only note that a strong local market will support the country's export efforts in a healthy way.

However, it may be assumed that silk will remain a special luxury fiber, which will continue to attract consumers in various parts of the world Since there will be more competition in general, it is very important that silk will be offered to consumers in new forms, such as interesting blends with other exciting fibers Since the total production of silk is only about 120000 tons or less than 02% of total production of textiles fibers, it would seem to make sense to use this unique fiber only for high quality products in order to give the fiber the merit, it deserves. In the context, the Indian non-mulberry silk may play a very crucial role.

"Wild silk" or "Non-mulberry silk" includes that fiber spun by various species of silk spinning insect, belonging to the Saturniidae, Lasiocampidae, Thaumetopoeidae, Paychidae families and others Among these, many species from the Saturniidae produce a large size cocoon which is made by porous cocoon filaments and is different from *Bombyx* silk The porous raw silks have a more complicated high shining than the *Bombyx* silk. Moreover, the porous cocoon filaments inhibit UV transmissivity by their repeated reflections in the textiles Also the fabrics woven by the porous silks are soft against the skin and are favoured by the consumers. On the other hand, sericin solution and powders from the wild cocoons or silks are used in cosmetics and are highly appreciated by users. For these reasons, wild silks are now recognized as a new material and have a high additional value which is activating the silk industry.

Raw silk produced by *Bombyx* is the most popular textile material for high class fabrics and its uniqueness is highly praised, especially its special sheen. However, the silks of *A. yamama* and *A. assama* are even more shiny than that of *B. mori*. The reasons probably because the wild silks have fine porous structure in the filament In a compact cocoon filament like that of *B mori*, the incident rays pass straight through the filament while in the porous filament, fine porous structures create repeated reflections, hence, a more complex shine Commercially, porous silk is highly valued because of its sheen, soft feel and the retention of desired warmth and comfort in the fabric (Akai, 2005).

This family makes a large cocoon which sells for a high price characteristics of the cocoon or the cocoon filament mainly its natural cocoon colour and porous filaments or thick and fine size are greatly appreciated by users The cocoons of *Antheraea yamamai* are beautiful (green in colour) and extremely high priced The *Antheraea pernyl* cocoon and silk are produced in great quantities in China and are used widely The *Samia cynthia ricini* cocoon is produced in India and other Asian countries and the filament is characterized by its porosity and fine size while the *Antheraea mylitta* cocoon is largest in size and filament *Antheraea assama* produces a golden coloured raw silk, which is well known only, restricted to India, more preciously North-East India and northern West Bengal, and holds a high Price (table 3).

Table 3 Silk price in India

	Price (Rs/kg)			
Variety	**2004**	**2005**	**2006**	**2007**
Mulberry silk	1053	1094	1343	1248
Taser silk	1450	1468	1575	1575
Eri silk	1100	1000	1000	1200
Muga silk	3150	2950	2950	3150

Source : Silk price, *Indian silk*, vol. **46**(2) : 2007, **45**(2) : 2006, **44**(6) : 2005

While mulberry silk is found in different parts of India, the North-Eastern Region of India including northern part of West Bengal is the only breeding ground of muga. Muga, famously known as "Golden silk", is exotic and comes in two colours – golden yellow and creamy white. However, the golden yellow is the desire of all its natural sheen is such that it is used for embroidery instead of zari. The attraction of its natural bright colour is such that it is rarely dyed and the sheen increases with every wash Also muga filters 80-88% of the ultra violet rays. Muga silk is produced by a variety of silkworm, *Antheraea assama*. In muga silkworm rearing, the worms feed on som and soalu leaves that are aromatic and rearing is done on trees The leaves that worms feed upon, determine the colour of silk. The region accounts for 6% of India's total silk production of which 100% from muga.

Sericulture activities occupies thousands of hectors of land, engaging millions families in North Eastern States and northern West Bengal. In Assam, Handloom is the second largest employer after agriculture. This region has a large pool of workforce in mugaculture and includes part-timer like housewives. The sector, besides being the primary employer of many, also augments the income of thousands of families.

During 2002-03, India imported 9054 MT of raw silk valuing USD 13374 million. This is indicative of the huge shortfall of India's production, particularly of fine silk and the North Eastern states of India and northern part of West Bengal has the potential to fill the gap

However, there are major constraints Firstly, the industry of the region has traditionally produced for markets within the region and has no knowledge of the market needs elsewhere. Although the products range from low end to high end, this primarily caters to regional tastes. The confined markets of the region cannot provide scope for growth of the industry. Therefore, there is an urgent need to identify and target new markets and develop products to cater to these markets.

Secondly, although the region is the exclusive producer of muga, this advantage is negated by the prohibitive cost of muga. Therefore, it is imperative that a niche market be created for muga. In addition, combination with other fibres should be experimented upon Muga is now being combined with eri and pashmina. Waste muga is being combined with eri to create thicker yardage and furnishing material. Another experiment being carried out is combining muga and mulberry silk with lycra and spandex to provide off the loom stretchiness and the resultant fabric is suitable for blouses and tops in formal western wear. The export promotion council for handicrafts has also developed designs with cotton or some other fabrics as the base and silk being the value adder such innovating design has created a niche market for itself.

Table 4 Production statistic for the year 2004-2005 in muga silkworm

States	Dfl (Lk Nos.)	Reeling Cocoon (MT)	Raw Silk (MT)
West Bengal	0.48	11.64	0.20
Assam	98	4918	104.00
Arunachal Pradesh	0.05	4.42	0.10
Manipur	1.23	2.18	0.10
Mizoram	0.4	5	0.10
Meghalaya	5.08	254	5.40
Nagaland	0.2	2.1	Nil
Uttaranchal	0.01	0.25	Negligible
Grand Total	105.45	5197.59	110

Source : *Indian silk*, September, 2005, Page 30.

Thirdly, the muga silk contributes very little to India's silk production (Table 4). Emphasis, therefo re, m ust be put on increasing production, particul arly in terms of productivity, as land becomes scarce and on the other hand, exploration of non-traditional area for mugaculture under this region is needed.

Finally, the most important matter is that seed production is considered as the backbone of sericulture industry. The concept of quality seed production in mugaculture is lacking in spite of the socio-economic and cultural relevance of muga silk production as an age-old practice. Though the applicability of indigenously developed know how has some positive impact, farmers often suffer crop losses due to pebrine infection or other factors Since, farmers themselves, without resorting to any prescribed scientific procedure, produced almost all the seeds, they often used to lose their crops or be satisfied with poor harvest. As a result, the muga silk production remained mostly stagnant ranging between 50-70 MT. Demand for muga layings could never be met to shortage of seed. The economic viability of a commercial grainage largely depends on the effective conversion of cocoons to laying the production ratio of muga seed during 1999-2004 is given in table 5.

Table 5 Muga Seed Production Ratio during 1999-2004

Year	Dfls reared (g)	Dfls produced (g)	Ratio (dfl : dfl)
1999-2000	20913	107290	1 : 5
2000-2001	16788	190103	1 : 11
2001-2002	19603	243446	1 : 12
2002-2003	18178	200967	1 : 11
2003-2004	14840	149364	1 : 10

The efficiency of any grainage improves with procurement of quality seed cocoons, proper preservation, and synchronization of emergence and maintenance of proper environmental conditions. Moreover, to overcome the huge gap between present annual requirement and overall commercial seed production. Private graineurs should be developed, though under UNDP assisted programs implemented the states of Assam, Meghalaya and West Bengal during 1999-2003 on mulberry sector some private graineurs were involved in activities (Table 6).

Table 6 Performance of private graineurs under UNDP assisted programme.

Particulars	Assam	Meghalaya	West Bengal
Private graineurs established (No)	57	6	6
Seed cocoon processed (No)	2835472	195345	231860
Dfls produced (g)	773635	74030	58350
Cocoon : Dfl	36 : 1	26 : 1	39 : 1
Income (Rs)	4641810	444180	350100

However, the post project scenario is not very much encouraging as most of the private graineurs lost the track and interest to continue the activity systematically. Hence, it is very important to give sufficient stress until the system became self sustainable. As sufficient plantation and reeling unit have already been developed during last decade, production of quality of eggs is need of the hour.

The present work has rightly being formulated following the objectives mentioned bellow:

(1) To identify seasonal influence on seed production and hatchability in order to harvest better yield of commercial cocoon crop at desired level.

(2) To standardize critical / optimum combination of key abiotic factors responsible for production of better quality and productivity of seed with higher hatchability.

(3) To standardize techniques towards synchronization of male and female moth emergence for production of assured fertilized eggs with higher hatchability.

(4) To standardized mating behaviour in view to manipulate them in production of quality eggs.

(5) To characterize the seed cocoons for practical use during commercial crop rearing season.

(6) To develop seed (eggs) preservation technologies for supply of better quality seed during commercial growing seasons.

CHAPTER - II

REVIEW OF LITERATURE

2.1. Environmental effect on muga silkworm seed production:

Muga-the golden yellow silk, is produced by the insect species *Antheraea assama* Westwood. (Lepidoptera: Saturniidae). It is multivoltine and polyphagous in nature. It feeds on various plants, viz *Persea bombycina* Kosterm (*Machilus bombycina* King), *Litsea monopetala* Pers, *Litsea polyantha* Juss, *L. citrata*, *L. Salicifolia*, *Magnolia sphenocarpa* and *Zizyphus jujuba.* Rearing of muga is conducted on *Persea bombycina* and *Litsea polyantha* in North-Eastern region of India, mainly in Assam and West Bengal particularly in CoochBehar district.

Muga, which is produced nowhere else in the world except in Assam, has of late been introduced in Mizoram, Nagaland and Arunachal Pradesh for production of seeds at higher altitude (Yadav and Goswami, 1987). Then muga finds its way to West Bengal after establishment of RMRS Research extension centre at CoochBehar. After conducting several trial rearings in different villages of Cooch Behar it has been established that muga culture is quite promising in this new zone (Singha *et al.,*1991). Different opinions are that the species is not only confined to north-eastern region rather it has a wide distribution both within the country and abroad. In India, the species is also available in Himachal Praesh, Uttar Pradesh, Sikkim, Gujarat and Pondicharry . It is also available in Bangaladesh, Srilanka and Indonesia. (Sengupta and Srivastava, 1995).

However, traditional practices in muga culture are mainly confined in Assam and North-Eastern States. The muga culture has become a part of the Assamese culture. Probably due to its restricted habitat in the North-Eastern Region, the muga silk insect, *Antheraea assama* has not drawn much attention of the people from the other parts of the world. (Thangavalu *et al* 1988).

Introduction of muga culture outside the North-Eastern India have not met successfully, probably due to lack of suitable climatic conditions. The climate of the North- Eastern India (21^0N to 29^030'N latitude and 89^046'E longitude) is very distinctive, which is sub-tropical having four distinct seasons viz. Summer (May-September), autumn (October-November), winter (December – February) and spring (March – April). The summer is hot and humid with very high rainfall. The maximum temperature never rises above 34^0C at the sea level and the high temperature is recorded only for a few days. Autumn and Spring are very pleasant and the minimum and maximum temperature ranges form 16^0C to 20^0C and 20^0C to 25^0C during these two season. Winter in moderate and the minimum temperature does not fall below 7^0C at sea level. Perhaps the distribution of *Antheraea assama* is restricted to North Eastern India due to this unique climatic condition.

Geographically Cooch Behar district of West Bengal $25^057'$ and 27^0 N latitude and $88^025'$ and $89^054'$ E longitude can be considered as a contiguous of Assam having more or less similarity in agro-ecological, socio-ethno-economic background. Climate of Cooch Behar district is also subtropical, humid with high rainfall having short spell of winter. Maximum rainfall receives during June-September and maximum temperature never rises above 33.2^0C with an exceptionally high 2-3 days peak of $35\text{-}40^0C$. Autumn and Spring are very pleasant and the temperature during this period ranges from 17.75^0C to 25.11^0C. Winter is moderate and the minimum temperature does not fall below 6^0C. Therefore, climate conditions of the district is more or less similar to that of Assam at least those places where muga culture is in vogue. This agro-climatic situation stimulates muga culture in Cooch Behar district of West Bengal (Ray, 2003).

Muga culture in Uttar Pradesh has also been tested by Sengupta and Srivastava (1995). The climate of the region varies according to their elevation from hot in the foothills to the freezing point in the Himala yas. The hills of Uttar Pradesh can be classified into the higher hills simulating temperate conditions and the middles hills being sub-tropical in nature. Doon valley particularly has been explored ($77^035'$ and $78^02'$ E and $29^057'$ and $31^02'$ N). The climate of the valley is temperate. Annual atmospheric temperature varies between 4 ± 1^0C to $41 \pm 10C$. Monsoon season extends from mid June to early October and annual precipitation varies between 1600 mm and 2500 mm, highest rainfall usually recorded during August. Climatically, three well-defined seasons are experienced in the valley. Summer from March/April to mid June – temperature ranges between 15^0C t o 35^0C with a brief spell of high temperature reaching up to 41^0C. Monsoon begins from mid June and lasts upto early October. Average temperature ranges from 20^0C to 32^0C while relative humidity sometimes reaches up to 95% and rainfall is generally maximum during August. Winter season begins from November and extends upto February, when the average maximum temperature is about 21^0C. In winter, about 50 mm to 60 mm rainfall is recorded. Therefore, the climate of Dehradun is ideal for muga culture.

Research works are mainly confined to North-East India. Among the seven North-Eastern states, muga production is confined mainly to the state of Assam. Assam is the only state for production of reeling cocoons, whereas other states have the privilege of producing major quantity of seed cocoons for commercial multiplication in Assam. Problems of muga industry includes vagaries of weather, pests, diseases, predators, untimely seed crop rearing, aged and improperly maintained plantation etc. Added to these, there is no specific race or seed organization for regular multiplication of basic seed meant for the production of commercial seed. Muga Seed Development Project was launched in the '80s to overcome the basic seed shortage but it could not fulfill the complete demand of basic seed. More then 95% of the commercial seed production is being vested with private rearers without any proper mother moth test. Hence as long as seed brood is free from pebrine disease, the seed produced by farmers may help them to realize good corps provided leaf quality and weather conditions are favourable. Muga silkworms thrive well when temperature and humidity ranges between 24-30^{0}C and 85-90 % RH respectively. It is difficult to posses the optimum condition all through the period of rearing especially during seed crop rearing.

Timely supply of adequate quantity silkworm seeds can only sustain the industry by ensuring successful cocoon corps. (Francis *et al.*,1995). The problem is that the growth and development of muga silkworm is very much susceptible to the climatic conditions and it reacts with every change in the environment, which reflects on the commercial characters of the silkworm. Being multivoltine in nature, it has five to six generations in a year. The climatic conditions favours the rearing of the muga silkworm during autumn (Kotia) and spring (Jethua) and hence commercial rearing is restricted to these two seasons only. However, as it is poly voltine in habits, rearing of unfavorable summer (aheruā and bhodia) and winter (Jarua) are also unavoidable and quite essential for survival of the silkworm. The muga seeds are multiplied during these unfavorable seasons only and hence known as seed broods. The productions during the seed broods are very poor, unsatisfactory and unpredictable. Occasional hailstorm, frequent raining and high temperature during summer and severe cold and poor growth of food plants during winter are inimical to the muga silkworm. (Sengupta *et al.,* 1992).

Being reared outdoor, the larvae of *A. assama* like those of *A. yamamai, A. pernyi* and *A. mylitta* have adjusted themselves to a certain degree against all kinds of selection forces of Nature (Crotch; 1956; Yamazaki, 1959). Various factors have shown to affect the success of silkworm cocoon production including environment (37%), leaf quality (38.2%), rearing technique (9.3%), silkworm race (4.2%), silkworm egg quality (3.1%) and others (8.2%). (Matsumara,1975). In 1933, Kogure opined that the silkworm could tolerate temperature upto 30^0C. Silkworm larvae become weak by rearing at higher temperature than 30^0C (Upadhyaya and Mishra (1991) and hampered growth enhancing the mortality (Mathur *et al.*, 2003). While Nirmal Kumar *et al.* (2005) observed on bivoltine *Bombyx mori* that higher temperature induces the silkworm to develop faster, mature early and spin the cocoon quickly. The opposite happens when temperature falls below the normal range. It has been recorded that environmental conditions are the main cause of variability in *A. mylitta* as the fecundity, hatchability, cocoon weight, shell weight, absolute silk yield, filament length, denier and sericine percentage varied during different season (Srivastava *et al.*, 1998).

In *Samia ricini*, the commercial traits such as cocoon weight, shell weight, pupal weight varied significantly during different seasons. Lower days of rearing period and life cycle during summer was associated with lower value of cocoon weight and shell weight and reverse was the case in winter season (Kar and Guru, 1998).

A. assama in relation to temperature and relative humidity in all the six corps was studied by Sahu *et al.* (1978). Profound effect of temperature was observed in incubation period, hatching percentage, larval – pupal periods, coupling and oviposition. 23-27^0C and 70-77% RH appears optimum for coupling as well as oviposition, while 19-26^0C and RH of 70% above was found to the optimum for hatching.

In *Antherea assama,* there was steady and significant increase in the hatching percentage along with the rise in temperature from 17^0C to26^0C, but a declining trend on hatchability was observed for 29^0C to 35^0C. The hatching percentage was significantly impaired at 35^0C. On the other hand incubation period and hatching duration are inversely proportional to the rise of temperature (Barah *et al.*,1993). According to them, the humidity regimes under individual temperature treatment, the humidity regimes of 65%, 75% and 85% had relatively much less effect on the incubation period and hatching duration but showed a significant improvement on hatchability in between the treatments. But in all temperatures, the humidity above 90% showed a relatively impaired hatching, which was significantly inferior to the other humidity regimes. According to Wigglesworth (1972), 90% RH showed an advance effect on hatching, such as a result is possible when some hygroscopic substance in the egg chorion is affected. The high atmospheric temperature and low RH persisted for quite long time resulted in huge pupal mortality, only one peak of emergence of moths occurred as against usual two peaks, low fecundity and higher egg retention in ovary in tropical tasar silkworm, *A. mylitta*. (Mathur *et al.,* 2005). Studying on West Bengal condition Saha *et al.* (2007) also observed that hot and humid summer and high precipitation impede the rearing of production breeds.

Seasonal changing of photoperiod also have effect on seed crop rearing as the light and dark schedules of the natural day in animals induce different kinds of fluctuations in growth and development and a combination of physiological mechanisms (Denilevskii, 1965) and particularly in insect. Photoperiodism regulates the growth and various physiological mechanisms (Beck, 1980). Masaki (1972) observed that photoperiod has a positive effect on synchronization of adult emergence in cricket. In each insect in population rhythms, circadian events compose 'allowed zones' or 'gates' through which egg hatching, eclosion or release of hormones may occur (Saunder, 1982).

Grainage performance during the pre-seed and seed corps and especially during Chotua and Aherua seasons suffer due to low humidity and low temperature (Chotua) and high temperature ranging from 26-36^{0}C and high humidity (74-76%) during Aherua and Bhodia seasons resulting in requirement of more number of cocoons for producing one Dfl (cocoon : Dfl ratio 5:1 or even more), poor moth quality and low to very low hatching (0-25%) due to exposure of the late age worms to high temperature (36^{0}C) during out door rearing and spinning under indoor condition. This has been identified as one of the major problems in muga culture that causes shortage in production of main commercial seed during kotia crop (Sahu, 2004).

In mulberry silkworm the effect of photoperiod on pupal characters and hatching has been reviewed (Janarthanan *et al.,* 1994; Benchamin *et al.,* 1990) and gating phenomenon has been demonstrated in egg hatching (Sivarami Reddy and Sasira Babu, 1990). In tasar silkworm, short days promote diapause development, while long days maintain diapause (Sakate *et al.,* 1982).

The role of photoperiod in the developmental processes and in the induction of pupal diapause in muga silkworm *A. assama* was studied. During short day length (LD 4.5 : 19.5 and LD 6 : 18), photoperiods of high intensity slowed down development rates but were not effective in inducing diapause in this insect. The effect of photoperiod on oviposition and hatching were also studied. Female laid more eggs under short-day than under long-day conditions and the short-day condition also showed higher hatchability (Mahanta and Goswami, 1986). When the larvae reared in different photoperiodic regimes (24L, 18L : 6D, 12L : 12 D and 6D : 18L) and in different season (spring, early summer, late summer, late autumn), temperature influences the effect of photophase in case of developmental period, food utilization and growth. High temperature and constant light as well as low temperature short photaphase are found deleterious. The sensitivity to photoperiod decrease towards instar when the larvae are more sensitive to temperature.

In mulberry silkworm, incubation of eggs under complete light or complete darkness leads to irregular hatching thereby reducing the hatching percentage (Chowdhury, 1984) and 12-18 hours light and 6-12 hours dark is effective photoperiodic regime for perfect and uniform hatching. 12-18 hours light/day is favourable for the embryonic development and uniform hatching (Meenal *et al.,* 1994).

Taking all these environmental factors under consideration egg production challenges in muga silkworm has been studied in North Eastern States. According to them, the success of commercial crops highly depends on the success of seed crop rearing when the environmental conditions are hazardous. During June-August, the environment is very hot and humid with a temperature range of 25-38 ^{0}C and heavy rainfall. Heavy loss of seed cocoons occur during this period. Moreover, the seed cocoons produced exhibit emergence of deformed moths, coupling inefficiency and infertility of eggs that badly affects the availability and fertility of eggs for the ensuing commercial crop rearing. Another seed crop rearing (including pre-seed) season in November – March when temperature fluctuates between 10 and 28 ^{0}C with drastic fall during night. Nearly 50% or more loss of seed cocoons occur in the grainage causing shortage of seed for subsequent commercial rearing.

In newly explored areas, the scenario is not as poor as Assam. In Doon Valley, fecundity of the DFLs was higher than average fecundity found under Assam conditions. Hatching percentage was also recorded much higher (81%) is comparison to that in Assam condition (55%). These are enough scope for extension of mugaculture in the hills of Uttar Pradesh especially in Dehradun because due to adverse climatic condition, the rearing of muga silkworm particularly the seed crops are very uncertain in northeast India (Sengupta and Srivastava, 1995).

However, another extension center is West Bengal particularly Cooch Behar district where the climatic contiguity with Assam explores successful mugaculture. Upon preliminary observation by Ray, 2003, it can be said that October –November is the main commercial crop-rearing season. Surprisingly during March-April the seed crop-rearing season, the fecundity observed 162.50 much higher than Assam.

After that, an investigation on muga silkworm rearing as well as grainage was undertaken during nine different seasons : Feb.-Mar., April –May, May-June, July-Aug., Aug.-Sep., Oct.-Nov., Nov.-Dec., Dec.-Feb. and Jan.-Mar. to identify the suitable season for commercial and seed crop rearing for successful introduction of muga culture in Terai Region of West Bengal, India, a newly explored area. Rearing and grainage parameters were better during Oct.-Nov. followed by April-May and minimum during July-Aug. (Ray *et al.*, 2005).

2.2 Effect of host plant on Seed production:

Cocoon crop of silkworm depends upon the developmental vigour of the silkworm breeds, which in turn, is further influenced by the nutrient availability from the leaves fed (Ito and Arai, 1965). Plants with higher protein contents were more readily accepted and supported growth better than varieties with lower protein content (Soo Hoo and Fraenkel, 1966). Zhang *et al.* (1991) also reported that, increase of protein content shortened the larval duration, increased larval weight and digestibility. Moreover, the weight of pupae, fecundity and weight of eggs increased with the rise of protein content. Hamano and Tsuchida (1989) noticed that the mortality of larvae was lowered with the increase of protein content in diet. Since, the principal constituent of Silk is protein; leaves with high protein content are more readily accepted by the worms and promote growth better than the varieties with low protein content (See Hoo and Fraenkal, 1966). Li and Samo (1984) reported that lower values of leaf moisture and protein content in the food recorded lower rates of larval growth, body weight and cocoon weight. Therefore, there exists difference between the host plants with respect to nutrient content.

In mulberry silkworm, Satyanarayan Raju *et al.* (1990) observed that the performance of Kosen was highly satisfactory, while Venugopala Pillai and Jolly (1985) observed that MR_2 variety was superior and closely followed by Kosen so far as rearing performance was concerned. However, Ghosh *et al.* (1993) reported that leaf quality as well as yield of the S_1 variety was better in Malda district of West Bengal than other varieties studied. Subba Rao *et al.* (1987) recommended TR_4, TR_{10} and S_1 varieties of mulberry for higher leaf yield in Jalpaiguri district under terai region of West Bengal. According to Das *et al.* (1995) nutritive quality of C_{763} was found superior to that of other varieties (Viz. S_1, S_{779}, S_{1635}, C_{1730}, C_{763}, C_{776} and Kajli) followed by S_{1630} and S_{1730} in gang tic planes of West Bengal.

Nutrient content observed best in Kosen followed by TR_{10} and rearing parameters observed best in TR_{10} followed by Kosen. However leaf yield of S_1 is highest, nearly double than Kosen and TR_{10} suggesting selection of S_1 for bivoltine silkworm rearing in Terai region of West Bengal with culture compensation (Ray *et al.*, 1998). Ghosh *et al.* (2007) reported that C_{1730} is the best variety so far as rearing of silkworm is concerned followed by S_{1630}, BC_259, TR_{10}, Kosen, S_1, Bombai local and Kajli in Eastern India.

In non-mulberry section, the influence of host plant was not reported so vividly because of poor systematic plantation mainly depending on forest. Tasar silk includes tropical tasar and oak tasar. While tropical tasar is produced by the silkworm *Antheraea mylitta* which feeds primarily on *Terminalia anjuma, Terminalia tomentosa* and *Shorea robusta*, the oak tasar is produced by *Antheraea proylei, Antheraea pernyi* and *Antheraea roylei* fed on different species of *Quercus sp* mainly on *Quercus lencotricophora.*

Out of the total 76.1 million ha. of forest area available in the tropical tasar cultivating states (Jharkhand, Bihar, Orissa, Maharashtra, Chhattisgarh, Madhya Pradesh, Andhra Pradesh and West Bengal) nearly 19.05 million ha of tasar food plants are estimated to be available in the tropical belt of which *Shorea robusta* (Sal) accounts for 87%. The other two primary food plants viz. *Terminalia tomentosa* and *T. arjuna* and the secondary food plants (Zizyphus jujuba, *Terminalia chebula, T. belevica, T. catappa, Lagerstroemia paniculata, Anogeissns latifolia, Syzygium cumini* etc.) account for 1.4 million ha. (13.1%) (Mohan Rao, 2007).

The states where oak tasar culture is practiced are Assam, Manipur, Himachal Pradesh, Jammu and Kashmir and Uttaranchal. Different species of oak tasar food plantation are spread over different districts of the states. It is estimated that 195103 ha of *Quercus lencotricophora*, 72735 ha. of *Q .floribunda* and 26577 ha. of *Q. semicarpifolia* are available in Uttarcnchal, the leading state in oak tasar culture. However, *Q. incana* and *Q. semicarpifolia* are available in the North-West, while *Quercus dealbata* and *Q. serratta* in the North-East (Khatri *et al.,* 2007). Effect of different morpho types of *Gueraus semicarpifolia* on the rearing of *A. proylei* revealed that rearing on thick, non-spiny leaves of *Q. semicarpifolia* were found suitable for better yield on *A. proylei* (Raja Ram *et al.,* 1998).

Among the three natural host plant, *Terminalia tomentosa, Terminalia arjunna* and *Zizyphus jujuba. T. tomentosa* was found to be most suited host plant for the larva of *A .mylitta* in all respects (Rath, 1998).

Eri silkworm (*Samia ricini* Donavan) is a polyphagous insect and feeds on a wide range of host plants. At present, as many as 24 plant species are known to host eri silkworms. *Ricinus communis* Linn. (Caster) and *Heteropanax frograns* Seen. (Kesseru) are the primary hosts and are principally utilized for feeding eri silkworms. *Manihot utilissima* Pohl, (Tapioca), *Evodia fraxinifolia* Hook. (Payam), *Ailanthus grandis* Prain (Barpat) and *Jatropha curcas* Linn. (Bhotera) are the secondary host plants and are used less frequently. Plants like *Plumeria actifolia* Poir (Gulancha), *Gmelina arborea* Roxb. (Gramani), *Pyms pashia* Ham, (Patangi), *Xanthoxylum alatum* Roxb. (Jaunsar) and *Stercvlia villosa* Roxb. are the tertiary host plants and their leaves are rarely used for feeding during acute shortage of leaves of primary food plants for some specific and shorter periods of larval life (Bindroo and Khan 2007).

Som (*Persea bombycina* Kost.) and Soalu (*Litsea polyantha* Juss) are the two principal food plants and Mejankari (*Litsea cubeba*) and Dighloti (*L. salicifolia*) are the secondary host plant of muga silkworm. Som is more prevalent in upper Assam, whereas soalu is more common in lower Assam. The lower Assam rearers now prefer som trees for production of muga cocoons due to their long life span and more resistance to stem borer attack as compared to soalu trees. Depending upon the leaf shape and size, four varieties of some have been identified of which Naharpatia is better than Ampatia, Jampatia and Kathalpatia. Similarly, in soalu two varieties have been identified depending upon leaf shape size and texture, of which the ovate variety is preferred by muga silkworm than oblong (Thangavelu *et al.,* 1988).

Systemic plantation is the regular practice of som and soalu. Systemic plantation of som is more prevalent than soalu. Eight morphotypes of som have been collected, identified and raised in germplasm bank at Regional Muga Research Station, Boko, Assam. The average growth parameters biochemical analyses of leaves of all morphotypes were studied. Similarly rearing performance and post cocoon parameters were also studied on eight morphotypes. The cumulative results revealed that some morphotypes 53, 56, 54 and 55 were found palatable, superior in effective rate of rearing, cocoon production, absolute silk yield, higher filament length and raw silk recovery percentage (Siddiqui *et al.,* 2007).

Bardoloi and Hazarika (1988) after assessing the response of *Antheraea assama* to its host quality opined that leaf moisture content of the som plant regulated the rate of ingestion by the silkworm : the higher the moisture content, the higher the feeding rate and vice versa. However, dietary water acted not as a phagostimulant but as diluent of nutrients. Therefore the silkworm had to ingest more to obtain the necessary nutrients for its growth and development.

A. assama consume significantly more leaves of som (139.69 g , 3.62 cm^2/day) than those of soalu (83.30 g , 5.36 cm^2/day). The body weight, water content, fresh and lean dry weight of lipid of larvae fed soalu were significantly higher than those of larvae fed som though there observed no difference between them in the leaves. Qualitative variation in fatty acid composition between host plants and larvae were negligible (Hazarika *et al.,* 1995).

Among the four food plants, the conc. of K was high in som, Mg showed the same pattern but the cone. of Fe was higher in soalu followed by som. The abundance of K, Mg and Fe in som and soalu may be one of the reasons for the selection of these species as primary food plants of *A. assama* ,these major elements play a vital role in the production of silk fibers (Unni *et al.*, 1996).

Females of *A. assama* that had been reared on soalu as the larval food plant showed significantly higher pupal weight and higher oviposition rates than those on som and other food plants. The number of eggs laid was significantly positively correlated with pupal weight which was the best estimator for fecundity.

Rearing performance of muga silkworm on different food plants viz. Som, Soalu Dighloti, Gonsoroi (*Cinnamomum glaucesens*) and a natural hybrid (Dighloti x Soalu) and different seasons viz. pre-seed crop Jarua (Dec.-Feb.), seed crop Chotua (Mar.-Apr.), commercial crop (May-June), pre-seed Crop Aherua (June-July), seed crop Bhodia (Aug.-Sept.) and commercial crop Kotia (Oct.-Nov.) based on larval duration, ERR and cocoon weight revealed that Som performed best during Jarua (Dec.-Feb) crop while Soalu performed best in all other seasons, the natural hybrid was next to some during Jarua Crop while it ranked third in all other seasons. (Bhattacharyya *et al.,* 2004).

Effect of different type of diet of Dighloti, Majankari, Som and Soalu leaves on the rearing on muga silkworm was studied by Raja Ram and Samson (1998). They recorded the larval weight of 8.16 gm and cocoon weight of 4.45 gm, which were significantly higher in the treatment fed on Soalu only. The Cocoon yield (32.2% ERR) was significantly higher in the treatment when first instar on Dighloti and second to fifth on soalu were reared while silk ratio percent was calculated higher (7.16%) in the treatment when some was used.

According to Ray (2003) in West Bengal context, the performance of silk production was better on som and for seed production, soalu was better. Upon combined effect, rearing of early stage larvae on soalu and subsequent stage on som is the best combination for both silk and seed production.

2.3 Manipulation of abiotic factors for seed production:

Wigglesworth (1972) proposed that temperature limits between which reproduction occurs are often much narrower than the range of temperature over which the other activities of the same species remains normal. Not only reproduction but also the development and fecundity of an insect are temperature dependent.

It has been observed that muga silkworm eggs took various lengths of time to complete the embryonic development at different temperatures. Within the limits, the relationship followed almost a hyperbola. The lower the incubation temperature, the higher was the time taken to complete the embryonic development. The middle section of development curve falling between 20^0C to 29^0C showed straight line indicating that the rate of development was directly proportional to temperature, which was supported by hatching percentage (Barah *et al.,* 1993). Similar results have been reported from *Sitobion avenae,* an aphid species and Ali (1982) in *Patanga succineta.* Development was slowing down with further increase in temperature (32^0C and 35^0C) and also indicated the possibility of being sub-lethal temperature, since the eclosion from the eggs got reduced drastically both from thermal treatments, ranging from 17 ^{0}C to 29^0C as well as room temperature. (Barah *et al.,* 1993).

In *Bombyx mori* also, with the increase in temperature from 14 to 34^0C, the incubation period decreased from an average 12.83 days to 8 days (Upadhyay and Gaur, 2002). Chaturvedi and Upadhyay (1990) has given some idea about the effect of temperature on incubation period of *B. mori.*

The ecological factors like temperature, relative humidity and photoperiod are notably variable, therefore, for the success of the industry, the consideration of these ecological factor on the seed production sector must be taken into account (Upadhyay and Gaur, 2002).

Less intense effect of humidity on egg hatching was observed by Barah *et al.* (1993) because 65%, 75% and 85% RH produced an almost similar effect while 90% showed an adverse effect on hatching.

In *Bombyx mori* also, the increase in relative humidity caused considerable decline in the incubation period from 13 days at 35% RH to the lowest level of 9.4 days at 80% RH (Upadhyay and Gaur, 2002). Tanaka (1964) working extensively on the effects of environmental factors like humidity on larval mortality, found the high humidity not only prolonged larval moulting period but also affected physiology of the larvae thus the larvae became weak and susceptible for diseases (Benchamin and Jolly, 1986).

Photoperiod has important effect on egg hatching. In *B. mori*, Meenal *et al.* (1994) opined that for uniform and perfect hatching, eggs should be incubated under 12-18 hrs. light regime other that no light, 8 hrs. light and 24 hrs. light condition. Upadhyay and Gour (2002) observed that the variation in photoperiod regime influenced the incubation period of *B. mori* eggs. Maximum duration of the incubation was 11.77 days at 6 hrs. light a day while it was minimum of 9.55 days at 18 hrs. light a day. According to Tsurumaki (1999) all adults of *B. mori* developed under short days at low temperature (15^0C and 23^0C) oviposited, only non-diapause eggs and those that developed under long days at high temperature (28^0C and 25^0C) oviposited, the diapausing eggs. Incubation of eggs under complete light or complete darkness leads to irregular hatching thereby reducing hatching percentage (Chowdhury, 1984).

In *A. assama*, during short day lengths (LD 4.5: 19.5 and LD 6: 18) slowed down development rates but were not effective in inducing diapause in this insect. Females laid more eggs under short day than under long day conditions and the short day condition also showed higher hatchability (Mahanta and Goswami, 1986).

2.4. Synchronization of moth emergence and coupling for seed production:

Wigglesworth (1972) proposed that temperature limits between which reproduction occurs are often much narrower than the range of temperature over which the other activities of the same species remains normal. Not only reproduction but also the development and fecundity of an insect are temperature dependent. Hence, it is imperative to study the impact of temperature on different developmental stages of an insect in relation to the fecundity and viability of the eggs.

In the life cycle of the silkworm refrigeration is usually restored to one or more of the four developmental stages viz. egg (Singha *et al.,* 1994) larva ,pupa (Tazima,1978) and moth (Tazima, 1978 ; Gowda, 1988) for various practical reasons. But strictly, the refrigeration is to be restricted to any one of the developmental stage only for avoiding deleterious effects (Jolly, 1983).

In commercial grainages the problem of synchronization of male and female moths arises. The emergence is adjusted either by changing the day of starting silkworm rearing or by refrigerating the eggs or cocoons or moths in cold storage .The usual practice is to refrigerate the male moths for a maximum period of 7 days and female for 3 days at 5^0C (Tazima, 1978 ; Jolly, 1983). The male moths can be refrigerated before or after copulation, which can be reused for further copulation (Benchamin *et al.,* 1990). Prolonged refrigeration of virgin female moths and its subsequent effect on egg production has also been studied (Singh *et al.,* 1994).

The mating capacity of male moths of bivoltine breeds and hybrids was studied by Benchamin *et al.* (1990) under repeated mating (six times) in a day and on six consecutive days with rest at 5^0C of male moths ,between mating Fecundity in multivoltine female percent was not influenced by different male parents .Other characters ,effective rate of mating (87.4 to 96.6%), laying yield (84.2% to 96.5%) and fertility (96.5 to 98.1%) differed significantly among different crosses and between pure breeds and hybrids as male parent. Differences between repeated mating in a single day and on consecutive days, in terms of effective rate of mating (95.8 vs. 90.0%), laying yield (85.6 vs. 93.4%) and fecundity (452.1 vs. 418.0) were found significant. All characters studied decreased significantly as the number of mating increased. The bivoltine hybrids could be used as male parent with added advantage of higher effective rate of mating, laying yield and fertility over pure breeds.

Singha *et al.* (1994) while studying the impact of refrigeration of bivoltine female moths on fecundity, viability and hatchability of eggs observed that the fecundity in general has not shown any significant difference after refrigeration of female moths up to

6^{th} day as compared to control .Similar observations were also made by Tazima (1962) ; Ayuzawa *et al.* (1972) and Jolly (1983) when virgin female moths were preserved at low temperature (5^0C) for three days. Gowda (1988) described that fecundity is reduced significantly after 3 days of refrigeration of female moth. In winter season the fecundity was significantly less after refrigeration of female moths from 1 to 6 days as compared with control (Singh *et al.*, 1994). However, Singh (1992) has described rich laying in winter seasons after 72 hrs refrigeration of the female moths and also observed comparatively better hatching in winter season after 72 hrs refrigeration of female moths .Singh *et al.* (1994), however, opined that the virgin female moths of bivoltine races can the preserved at low temperature (5^0c) as and when required for 6 days to synchronize the mating in summer and rainy season. Such a practice is not advisable in winter season even for one day. Narasimhanna (1986) reported that even four hours coupling was sufficient in mulberry hatching and he developed suitable technique to get better quantity seed in mulberry silkworm.

At the outset of the emergence season, the males of Indian tropical tasar silkworm, *Antheraea mylitta* Drury, outnumbered the females and towards the end of the season, the trend it was reversed. As at lower temperature, the longevity of insect increased, especially in non-feeding adults (Clerk and Rockstein, 1964 and Ojha *et al.* 1996) explored the possibility of preserving males to be used for mating, if possible, several times. The effect of such refrigeration was analyzed by using performance indicators such as egg laying coefficient, mating efficiency and hatching percentage. Mating percentage and egg laying coefficients were statistically similar in the females coupled with 4 x males kept in refrigerated condition and at room temperature. Eggs obtained from females mated with refrigerated 5 x and 6 x males hatched, though at a lower percentage (48.45% in 5x and 41.88% in 6x males). Hatching was negligible after mating with refrigerated 6x and non-refrigerated 5x males. During scarcity of males in large scale of grainage, about 40 to 50% of eggs could be utilized if males were refrigerated between pairings and effectively used five or six times. Ojha *et al.* (1996) further opined that males of *A. mylitta* could be utilized for mating upto 8 times through refrigeration.

In non refrigerated *A .mylitta* moths, the egg laying co efficiency registered a declining trend when the same male was used repeatedly and this substantiate the fact that fecundity enhancing substances (FES) get depleted after every mating (Ravi Kumar *et al.,*1993).

Jolly (1987) reported that six hours coupling duration is better to get maximum hatchability in case of *Antheraea mylitta* eggs.

Maurya and Mishra (1993) carried out studies to evaluate the optimum coupling duration to get maximum fecundity and hatchability in oak tasar silkworm *Antheraea proylei*. The duration of coupling taken into consideration was one, two, three and four hours and compared with six hours coupling as control as it is the normal practice adopted in oak tasar grainage. The average no. of eggs recorded per female were 128 ± 6.06, 140 ± 10.92, 132 ± 8.07 and 138 ± 5.71 respectively and in control 119 ± 3.22 eggs only. The hatching percentage was observed which ranges between 55-69% and in control, it was 59%. As per the results obtained, there was no marked difference in the fecundity and hatchability percentage at different hours of coupling duration. So they concluded that two hours of coupling duration was sufficient instead of six hours to obtain optimum fecundity and hatching of the eggs. Mating, fertility and survival probability in male moths of *Antharaea mylitta* declined significantly with advancing age. Virgin males kept in dark showed better survival probability and survive upto 9 days where as, virgins in natural condition survived up to 8 days. Mating has a significant effect on survival of males .Regular mating leads to a lesser degree of survival than other groups .The survival probability observed was in the order of mated regularly < mated alternatively < mated on day 0 < mated on day 1 < mated on day 2 < control < virgin kept in dark. Mating possibility and fertility in the male moth declined to zero after four natural mating. Irrespective of mating status, the mating success and fertility declined with aging. Natural mating was not effective at the age of day 4. In the single mating, both mating success and fertility were considerably low when mating was effected on day 2. Weight of male moth declined significantly with advancing age but it was more pronounced in mated ones (Rath, 1998).

Such exercise was tried in *Antheraea assama,* muga silkworm for the first time by Barah and Sahu (2003). It revealed that duration of mating did not play any role in oviposition as the fecundity per female did not show any variation and remained at par with control. But the hatchability was significantly affected at 1, 2 and 3 hrs duration of mating. However, 4 hours mating duration and above did not effect the hatching performance, hence minimum 4 hrs mating duration was found optimum for successful fertilization of all the eggs of the female. Coupling aptitude of the male moths was decreased gradually with age. Beyond 24 hrs of age, coupling aptitude significantly deteriorated linearly in comparison to control showing only 32.5% natural coupling at the age of 96 hrs (4 days). All the females laid almost equal number of eggs in each treatment. Hatching performance of the eggs also decreased linearly with the age of male moths showing significant variation with control beyond 24 hours of age. However, the coupling aptitude (hatching) were not affected up to 24 hrs of age of the males. Coupling aptitude of male moths remained indifferent from control (95%) even is second mating (90%) when 4 hrs. intermittent rest period was allowed to the males in between the pairings. But 6 to 8 hrs. intermittent rest in between the pairings resulted in significant decrease per fall of coupling aptitude in second mating, which may be due to aging of the male moths. Coupling aptitude dropped down to a significant level in the 3rd mating irrespective of the period of rest. It was observed that oviposition had no relation with number of mating as well as with the period of intermittent rest of the male moths. They further mentioned that allowing 4 hours intermittent rest in between the pairings, even in the 3rd mating, above 60% hatching could be assured.

2.5. Characterization of Cocoon for selection of seed cocoon:

The correlation of female pupal weight with fecundity was studied in bivoltine silkworm *Bombyx mori* L. Positive and highly significant correlation existed between female pupal weight and fecundity (Sharachary *et al.* 1980; Gowda *et al.* 1988 and Shaheen *et al.,* 1992). According to Nagalakshmamma (1987) and Gowda *et al.* (1988) male pupal weight has no impact on fecundity in *Sanmia cynthia ricini*, a preliminary study was done by Nagalakshmamma (1987) who gave an indication about the female pupal weight to influence the fecundity irrespective of any dimension of male pupae used in mating after emergence. In females of eri silkworm the number of eggs laid was correlated with the pupal measurements like pupal weight, body length and body width. All the measurements considered were found to be genuine estimators of the fecundity, however, the pupal weight was the best estimator of fecundity.

Miller *et al.* (1982) reported significant correlation between the number of mature eggs and total eggs, concluded that the pupal weight was the best estimator of number of matured eggs in *Antheraea Polyphemus* (Gamer).

It is evident that a correlation between the dimensions of the pupae of *Antheraea mylitta* and egg laying exists and the pupae with larger dimensions is 10.5 ± 0.49 g weight, 4.5 cm abdominal girth and 3.5 cm abdominal length by larger number of eggs as compared to those with shorter dimensions with the observation that (Badhera,1992). Pupal weight was the best estimator of fecundity. Detailed works had been done by Dubey *et al.* (2005) on selection of seed cocoons in *Antheraea mylitta* and its correction with fecundity and hatching. Pupal weight has been identified as one of the estimator for selection of seed cocoons. Pupae were segregated sex-wise under different weight groups ranging from extreme high to extreme low. The study indicated that the medium weight range of male (8.50-10.59 g) and female (10.54-14.29 g) pupae were distributed abundantly in the normal population of first crop harvested seed cocoons. The study also indicated that this medium weight range of both male and female seed cocoons overlaps each other comes in the way of selecting the male and female seed cocoons for the grainage. The emerging adults from various pupal weight groups were crossed reciprocally in all possible combinations .The female pupal weight was observed as an estimator for fecundity, whereas male pupal weight did not contribute any significant influence either on fecundity or on hatching.

Correlation and regression studies between pupal weight and fecundity of muga silkworm, *Antheraea assama* was also done on different food plants. According to Barah *et al.*, (1989) females recorded on soalu showed significantly higher pupal weight and higher oviposition rates than those on som and other secondary host plants. The number of eggs laid was significantly positively correlated with pupal weight which was the best estimator for fecundity. Yadav *et al.* (1992) while observing the association of fecundity with cocoon weight, pupal weight and shell weight of muga silkworm during two commercial broods reported that cocoon weight, pupal weight and shall weight were positively correlated with fecundity.

2.6. Short-term cold preservation for seed production:

The structure of egg is the determiner of the pattern of development (Boswell and Mahowald, 1985). The structure and development of eggs in various insects have been described by many workers (Engelmann, 1970; Jura,1972; Balinsky ,1981). The first detailed study on the development (embryogenesis) of silkworm *Bombyx mori* egg was carried out by Toyama (1902). Since then embryological studies were confined especially to solve the practical problems, such as identification of suitable stages for refrigeration of early embryos and the initiation, continuation and termination of diapause in order to develop an effective system for long-term cold storage of silkworm eggs.

Takami (1969) was apparently the first who published a review on the embryogenesis of the silkworm, *Bombyx mori.* Morphological changes occurring during different embryonic stages in the silkworm, *B. mori* were described (Nakada, 1932; Takami and Kitazawa, 1960). In these studies, morphological changes of embryos were used to assess their long term survival. Moreover, the tolerance of eggs to cold storage varies with the stages of embryonic development besides genotypes because of adaptation phenomenon, metabolic changes and also genetic variations etc. (Salt, 1961 ; Rockstain, 1974 ; Sander *et al.,* 1985 and Sonobe *et al.,* 1986) and hence the recent studies on silkworm eggs become more concerned with physiology, biochemistry and metabolic activity associated with termination of diapauses (Yaginuma *et al.,*1990;Yamashita and Yaginuma, 1991) for effective handling.

It is believed that for any particular individual there is a precise limit to the time during which it may survive exposure to a particular lethal temperature and this may be true for any stage of the life cycle of that individual (Andrewartha and Birch, 1954). Watters (1967) found that eggs of *Trilobium confusum* less than four hours old were readily killed on exposure at 5^0C or 10^0C for five days but older eggs become progressively more resistant to these temperatures and nearly 30% of three to four day old eggs survived a 15-day exposure. As it is a already established from similar studies of other workers (Howe, 1967) that the first stages of embryonic development of insect eggs are very crucial and sensitive to low temperature.

Dutta *et al.* (1972) determined the effect of preservation at low temperature (5-7 ^{0}C $\pm$ 1 ^{0}C) on the hatching of multivoltine silkworm *Bombyx mori* L. eggs following incubation for different periods. Results indicated that the eggs incubated for 1.5 days at room temperature are most suitable for long time preservation. In general, eggs incubated for shorter periods are able to withstand preservation for larger periods in comparison to eggs incubated for a larger period and then subjected to low temperature preservation .The results indicate different scheduled of preservation which can successfully be utilized by the Sericulturists where postponement of hatching is needed for synchronization or solving technical difficulties related to distribution of layings.

Ibohal *et al.* (1987) reported that oak tasar eggs (*Antheraea proylei*) can be cold stored up to 30 days without any adverse effect on hatching ,effective rate of rearing ,cocoon weight ,shall weight and reliability. Pandey *et al.* (1992) has reported that oak tasar silkworm eggs can be stored in refrigerator only for 17 days. Pandey *et al.* (1992) observed that they can be stored up to 10 days without any adverse effect on hatchability. After 20 days of cold storage less than 1% embryonic death occurred between 7 and 11$\pm$ 2^{0}C where as after 30 days upto 3% embryonic death occurred at the same temperatures. The embryonic death was relatively more up to 6.46% at 5$\pm$2^{0}C upto 30 days .But after 40 days of cold storage only 9.8% embryonic death occurred at 5$\pm$2^{0}C where as upto 15.5% embryonic death occurred between 7 and 11$\pm$2^{0}C. It was further observed that eggs of only one day age could not survive even for 10 days of cold storage at 5$\pm$2^{0}C. Thereafter, from the second day onwards the growth of the developing embryo can be temporarily arrested by cold storage up to 10 days without any loss and upto 30 days with less than 2% loss and upto 40 days with less than 10% loss. Effect of refrigeration on the hatching of *Antheraea Proylei* eggs was studied by Biren Rana *et al.* (2002) also to determine the suitable age of eggs, temperature and duration of refrigeration in order to delay hatching. 24, 48 and 72 hours old eggs were subjected to cold storage at 0, 5, 10 and 15^{0}C for a period of 5-35 days, than incubated at 24 $\pm$ 2^{0}C and the hatching was recorded. Observation of eggs at 0^{0}C revealed maximum adverse effect on the hatchability of 24 h old eggs with all durations of storage while at 15^{0}C irregular hatching started beyond 15 days of refrigeration period. The adverse hatching in eggs of all ages was highest at 10^{0}C with more than 60% hatching upto a period of 20 days and declined thereafter. The age of eggs and the period of refrigeration at four different temperatures were observed to have a significant effect on the percentage of hatching.

The effect of temperature on the incubation of *Antheraea yamamai* eggs was observed by Zhang *et al.* (1998) who reported that the egg embryos did not develop below 5.5^0C, partly incubated between $7\text{-}10^0$C and the incubation became rapid correspondingly with the rise of temperature from $7 - 30^0$C.

Nangia and Nageshchandra (1988) recorded good hatching in the eggs of *Samia cynthia ricini* (laid within 72h) upto a period of 15 days when refrigerated at 0^0C. They further observed that storage of eggs at $5\text{-}10^0$C for 5-10 days gives the highest effective rate of rearing. Vishwakarma (1982-83) observed that at $7 \pm 2\ ^0$C, 3days old eggs of *P. ricini* in summer and 5 days old eggs in winter are more resistance to cold than at 3 1^0c (Govindan *et al.*, ,1980) where refrigeration beyond 5 days of ate has an adverse effect on hatching.

In *Antheraea assama* an attempt has been made by Biswas and Ray (2007) to avoid rearing during mid June to mid August reflecting poor supply of seed during main commercial season (Oct. – Nov.) by refrigerating the cocoons from previous commercial crop (May –June). From the results it can be said that 15 days cocoon preservation can delay the moth emergence for 10 days, adult moth preservation for 5 days and eggs after 24 hrs incubation for 21 days.

Sengupta and Singha (1974) studied the refrigeration of muga seed cocoons at 4 ± 1^0C for 5 to 50 days and found gradual reduction after 40 days of preservation. Subha Rao and Choudhury (1976) also observed the effect of preservation of muga cocoons at low temperature. According to them muga pupae could be preserved at 2.5 to 5^0C for more than 75 days in winter and 30 days in summer to delay in the moth emergence. Thangavelu *et al.* (1985) preserved muga seed cocoons at 5 and 10^0C and at higher altitude (2590m). They obtained better results after 3 months of preservation. Several other studies (Choudhury *et al.* 1980 and 1985 and Bora *et al.* 1980, 1990 and 1992) also revealed that refrigeration of muga seed cocoons at 5 to 12^0C for 10 to 120 days gave satisfactory results in terms of moth emergence, pairing, fecundity and hatchability. In a study on preservation of muga seed cocoons of autumn crop at 8 ± 1^0C and 60-70% RH, could delay moth emergence till 60-80 days as compared to 30 days in control Khanikor and Dutta (1998). A preservation for 35 and 40 days could be suitably utilized for 'Chotua' crop (Feb.-Mar.) by overcoming the hazardous winter crop (Dec.-Feb.). Khanikor and Dutta (1998) further opined that the moth emergence could be delayed from a normal period of 28-30 days to 60-120 days in case of autumn cocoons, 40-45 days to 80-100 days in the case of late autumn cocoons and 14-18 days to 30-42 days in the case of spring cocoons .Based on reproductive parameters of preserved individuals ,growth and cocoon parameters of their progenies suitable results were obtained from the lots preserved for 35-45 days in commercial autumn crop, for 45-60 days in late autumn crop and for 20-30 days in commercial spring crop. Declining trends in all the parameters were observed beyond these periods of preservation of seed cocoons has been taken by Sengupta *et al.* (1995) where ten day old cocoons were kept at 7^0C and 10^0C showing safe preservation at 10 ^{0}C for 45 days without affecting their reproductive physiology.

Singha *et al.* (1998) opined that the longest embryonic stage which occurred at 36 hours of oviposition during May and 114-126 hours of oviposition during November exhibited resistance to low temperature treatment without impairing hatching in muga silkworm.

Seed cocoons of autumn crop of muga silkworm were preserved at low temperature regimes of 5 ± 1^0C, 7 ± 1 ^{0}C and 9 ± 1^0C for 30, 40, 45, 50, 55, 60, 65, 70 and 75 day. Declining trend was observed in all the parameters, viz. moth emergence pairing, fecundity and hatchability. Moth emergence could be delayed up to 60-120 days against 28-30 days in control. Better results were obtained in 35, 40 and 45 days of preservation compared to the rest. Muga seed cocoons of autumn crop can be preserved effectively for 30-45 days to delay moth emergence to avoid the prolonged Jarua crop and to synchronize with the subsequent main seed crop (Chotua) for raising the commercial spring (Jethua) crop (Khanikor and Dutta, 2006).

Finally, Upadhayay and Pandey, (2000) opined that the weight of cocoon obtained from the long-term refrigerated eggs was of low grade but the cocoon obtained from the short-term refrigerated eggs was of comparatively better in weight, hence suggesting avoidance of long-term preservation as far as possible.

CHAPTER - III

MATERIALS AND METHODS

3.1 Geographical location :

Cooch Behar district of West Bengal is under Terai region and is situated in the north-eastern part of West Bengal, adjacent to Kokrajhar and Dhubri district of Assam. Terai zone is situated between $25^0 57'$N and 27^0N latitude and $88^0 25'$E and $89^0 54'$E longitude. This northern region of West Bengal is situated along the foot of Karseong and Kalimpong hills and Bhutan hills in the north, Bihar border on the west and Assam border on the east. It includes Siliguri Sub-Division of Darjeeling district and entire district of Jalpaiguri and Cooch Behar and Islampur Sub-Division of North Dinajpur District. The total geographical area of the zone is 12025 sq. Km., which is 13.5% of the state area. Rural population comprises about 90% of the population of the zone. Cooch Behar district of West Bengal is lies between $26^0 57'40''$N and $26^0 32'20''$N latitude and $88^0 47'44''$E and $89^0 54'35''$E longitude. The altitude of the district is 43m above MSL.

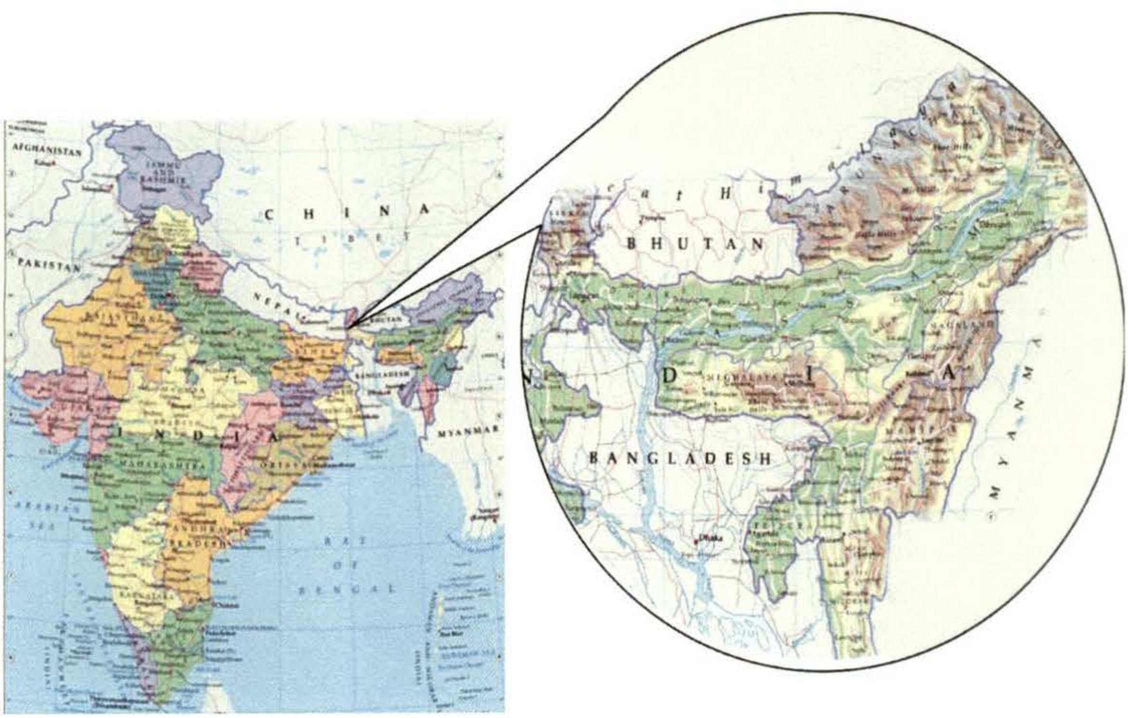

Plate 1 showing different regions of Eastern and North Eastern India where muga culture is in practice

3.2 Climate :

The climate of the zone is sub tropical and humid in nature. Average annual rainfall about 80% is received from South-Western monsoon during the rainy months of June to September. The range of minimum temperature of the area is 11.19 – 30.24^{0}C while the maximum is 20.54 -34.24^{0}C. The relative humidity of the area at 8.30 am is 58-89% respectively in March – July. The relative humidity in the afternoon at 5.30 pm is 48 – 81% respectively in March – November. On the whole the area has a humid and warm climate excerpt having a short spell in winter, December – February.

3.3 Experimental Site :

Rearing :

The experimental rearings of muga silkworm were conducted at Khagrabari Research Extension Centre (Cooch Behar, West Bengal), Regional Muga Research Station (Boko, Assam), Central Silk Board, India and at Khagrabari State Sericulture Farm (Cooch Behar, West Bengal), Govt. of West Bengal as well as in the adopted farmers field at Nalongibari, Dangarhat of Cooch Behar – I Block and Hatidura, Atialiguri of Cooch Behar – II Block.

Experimental rearings of muga silkworm were conducted at the instructional plantation of Acharya B. N. Seal College, Cooch Behar, West Bengal.

All rearings were conducted in natural out door condition.

Grainage:

Grainage operation and other studies were conducted at Muga Research Laboratory (MRL), P.G. Department of Zoology, Acharya B. N. Seal College, Cooch Behar, West Bengal.

3.4. Insect :

Among most successful animal groups in terms of species, insects are predominant one an estimate of total number of leaving species ranges from 10 – 30 million (Pearse *et al.*, 1987). Muga silkworm *Antheraea assama* Westwood is a highly heterogeneous unique and semi domesticated multi voltine strain of Saturniidae family of Lepidopteran insect endemic to Assam, adjacent foot hill of Meghalaya, Nagaland, Arunachal Pradesh and Mizoram. However, it grows under semi-domesticated conditions in North Eastern States of India but it has immense possibility of expansion in area and increasing productivity under befitting agro-ecological situation of Terai zone of West Bengal.

As it is wild in nature, so rearing was done in the field. At the time of rearing 4-6 big trees together, cover with a mosquito net (rearing net) to kept them away from the natural enemies like birds, snakes, wasps, britle, lizard etc.

3.5 Food plants or host plants :

Muga silkworm is polyphagous in nature. It feeds on various plants, viz *Persea bombycina* Kosterm (*Machilus bombycina* King), *Litsea monopetala* Pers, *Litsea polyantha* Juss, *L. citrata*, *L. Salicifolia*, *Magnolia sphenocarpa* and *Zizyphus jujuba.* In present investigation larvae were reared on the two principal host plants namely *Persea bombycina* King (Som) and *Litsea polyantha* Juss. (Soalu).

3.6 Rearing of silkworm :

During different seasons in a year, rearing was done at different field alternately. Immediate after completion of rearing the pruning of tree, liming of soil, organic manuring, bleaching powder spray etc. were done for the purpose of increasing new leaves, changing of soil pH, growth and free from larvae eating hunter ants, beetles etc. respectively.

During dry season March – April proper irrigation was maintained to avoid the water scarcity.

3.7 Seasonal influence of grainage parameters of muga silkworm :

Muga silkworm rearing were conducted during all the seasons under consideration, namely February – March, April – May, May – June, July – August, August – September, October – November, November – December, December – February and January – March and after harvesting cocoons subsequent grainage operations were done in the laboratory.

Grainage parameters like potential fecundity (PF), realized fecundity (RF), fecundity up to 3 days (3DRF), egg retention within the female body (ER), hatching number (HN) and hatching percentage (HP) were observed in all the seasons. Data obtained from each grainage were recorded and analyzed statistically by a suitable method.

Potential fecundity (PF) = Potentiality to egg production by a gravid female moth.
Realized fecundity (RF) = No. of egg laying by a gravid female moth.
Fecundity up to 3 days (3DRF) = No. of egg laying by a gravid female moth upto 3 day during laying period.
Egg retention (ER) = After successful laying egg retention within the female body.
Hatching number (HN) = No. of hatched larva from a single laying.
Hatching percentage (HP) = Percentage hatched larva of respective realized fecundity.

During grainage after moth emergence, natural coupling was allowed after decoupling females laid eggs on *Kharika.* Intrinsic factor influencing seed production were recorded as pupal period, emergence period, mating period, oviposition period and incubation period.

Pupal period = Period between spinning of larva (cocooning) and emergence of adult (days).
Emergence period = Time gap between head appearance and emergence of hole body (minute).
Mating period = Time span (duration) of coupling (hrs.).
Oviposition period = Duration of laying (days).
Incubation period = Time from laying of eggs to hatching of larva (days).

Day-wise cocoons were harvested from the main seed crop and pre seed crop rearings after moth emergence were allowed to couple naturally. From the onset of egg laying day wise collection of eggs were maintained and also kept the collected eggs separately in the hatching box to evaluate the day wise hatching percentage.

All the treatments were replicated thrice taking average layings of 25 coupling as one replication.

All the intrinsic and grainage parameters were studied separately nourished on both som and soalu plant during all the nine periods.

3.8 Manipulation of abiotic factors :

3.8.1 Manipulation of temperature :

To find out the temperature suitable for seed production, five (5) set of temperature ranges were taken under consideration namely T_1 (15^0C), T_2 (20^0C), T_3 (25^0C), T_4 (30^0C), T_5 (35^0C) during the grainage operations cocoons obtained from seed crop rearing of March – April and August – September. The hatching number (HN) and hatching percentage (HP) were studied.

3.8.2 Manipulation of relative humidity (RH) :

To determine the RH suitable for seed production, four (4) humidity range were selected namely R_1 (65%), R_2 (75%), R_3 (85%), R_4 (above 90%) and hatching number and hatching percentage were recorded.

3.8.3 Manipulation of temperature and RH :

To study the combined effect of temperature and humidity all the 5 temperature regimes and 4 humidity regimes were combined i.e. under each temperature range 4 humidity range were selected. The total experiment was conducted in Environmental Test Chamber regulating the desired temperature and humidity. Parameters like incubation period, hatching duration and average hatching percentage during both the seasons were studied.

3.8.4 Manipulation of temperature, humidity and photoperiod :

After screening of the effect of temperature and relative humidity were observed with five (5) photoperiod regimes namely 6 L, 9 L, 12 L, 15 L and 18 L condition in Environmental Test Chamber.

3.9 Synchronization and Mating behaviour :

3.9.1 Synchronization :

3.9.1.1 Synchronization in normal condition :

After harvesting of cocoons were allowed to emerge, male and female moths emerged upto 4 days were allowed to couple in all possible combinations and 16 combinations were taken under consideration as depicted in table 7.

Table 7 Different mating combinations in normal condition of muga silkworm

Treatment	Coupling Combinations
T_1 :	1st day emerged male x 1st day emerged female
T_2 :	1st day emerged male x 2nd day emerged female
T_3 :	1st day emerged male x 3rd day emerged female
T_4 :	1st day emerged male x 4th day emerged female
T_5 :	2nd day emerged male x 1st day emerged female
T_6 :	2nd day emerged male x 2nd day emerged female
T_7 :	2nd day emerged male x 3rd day emerged female
T_8 :	2nd day emerged male x 4th day emerged female
T_9 :	3rd day emerged male x 1st day emerged female
T_{10} :	3rd day emerged male x 2nd day emerged female
T_{11} :	3rd day emerged male x 3rd day emerged female
T_{12} :	3rd day emerged male x 4th day emerged female
T_{13} :	4th day emerged male x 1st day emerged female
T_{14} :	4th day emerged male x 2nd day emerged female
T_{15} :	4th day emerged male x 3rd day emerged female
T_{16} :	4th day emerged male x 4th day emerged female .

The experiment was undertaken in two main seed crop-rearing seasons namely March – April and September-October. Parameters like coupling efficacy, fecundity and hatchability were recorded.

3.9.1.2 Synchronization by short-term cold preserved condition :

Preservation of adult moth after emergence upto 3 days at 10 ± 1^0C in BOD incubator were done and coupled in all possible combinations : 15 with a control batch of fresh

Table 8 Different mating combinations in preserved condition of muga silkworm

Treatment	Coupling Combinations
T_1 :	Fresh male x Fresh female
T_2 :	1Day Preserved Male x Fresh Female
T_3 :	2Day Preserved Male x Fresh Female
T_4 :	3Day Preserved Male x Fresh Female
T_5 :	Fresh Male x 1Day Preserved Female
T_6 :	Fresh Male x 2Day Preserved Female
T_7 :	Fresh Male x 3Day Preserved Female
T_8 :	1 Day Preserved Male x 1 Day Preserved Female
T_9 :	1 Day Preserved Male x 2 Day Preserved Female
T_{10} :	1 Day Preserved Male x 3 Day Preserved Female
T_{11} :	2 Day Preserved Male x 1 Day Preserved Female
T_{12} :	2 Day Preserved Male x 2 Day Preserved Female
T_{13} :	2 Day Preserved Male x 3 Day Preserved Female
T_{14} :	3 Day Preserved Male x 1 Day Preserved Female
T_{15} :	3 Day Preserved Male x 2 Day Preserved Female
T_{16} :	3 Day Preserved Male x 3 Day Preserved Female

male and female during March – April and September-October. Coupling efficacy, fecundity and hatchability were studied as the effect of preservation.

The hatched larva (hatching yield), the ultimate indicator of output of grainage operation was calculated in both the seasons with the formula as expressed below:

Hatching yield = [Coupling efficacy (%-age) x fecundity x hatching percent]

hatched larvae per 100 couplings

3.9.2 Mating behaviour :

3.9.2.1 Mating duration :

To find out the optimum period of coupling for successful fertilization of eggs, male moths were allowed to mate for 11 different durations. For this standardization 11 treatments were selected from 2 hours to 12 hours with one hour interval, egg laying and egg retention were taken as quantity production parameters and hatching number and hatching percentage were taken as quality production.

9.3.2.2 Repeated mating :

After standardization of mating hours, subsequently another experiment was undertaken to determine the mating times : multiple coupling capacity of male moths . In this experiment males were exploited upto 6 times (T_1 to T_6) during September – October and upto 4 (T_1 to T_4) times during March – April with fresh female : unmated and egg laying, retention and hatchability were taken as key parameters.

3.10 Characterizations of seed cocoons :

Female cocoons were available from 4.00 to 8.50 g. Preliminary screening of seed cocoon was based on cocoon weight, length and diameter and their individual as well as combined reflection on fecundity, hatchability and egg vigour were the key parameters Cocoons were grouped into four category viz. light, average, moderate and heavy.

Furthermore, cocoons were grouped under seven weight ranges separately for male and female with a same limit of weight. The groups were extreme low, lower, low, medium, high, higher and extreme high. Distribution patterns of weight range percentage

Table 9 Different female cocoon groups selected for primary screening

Treatment	Weight (g)	Length (cm)	Width (cm)
Light (T_1)	4.50 - 5.49	3.50-4.00	5.52-5.90
Average (T_2)	5.50 – 6.49	4.00-4.50	5.90-6.30
Moderate (T_3)	6.50 - 6.49	4.50-5.00	6.30-6.70
Heavy (T_4)	7.50 and above	5.00-5.50	6.70-7.10

were calculated. After emergence, fresh males and females were utilized for mating. Although 49 combinations alongwith one control batch (randomly selected cocoon) were selected and Parameters like fecundity, hatchability and egg vigour were recorded.

Table 10 Wide range of male and female cocoon weight groups selected

Cocoon weight groups	Cocoon weight (g)	
	Male	Female
Extreme low	M_1 : 2.50-2.99	F_1 : 4.50-4.99
Lower	M_2 : 3.00-3.49	F_2 : 5.00-5.49
Low	M_3 : 3.50-3.99	F_3 : 5.50-5.99
Medium	M_4 : 4.00-4.45	F_4 : 6.00-6.49
High	M_5 : 4.50-4.99	F_5 : 6.50-6.99
Higher	M_6 : 5.00-5.49	F_6 : 7.00-7.49
Extreme high	M_7 : 5.50-5.99	F_7 : 7.50-7.99

Where only female cocoons were considered, F_1 to F_7 were treated as T_1–T_7. Weight of cocoons was measured by digital balance with one gram in thousand fraction sensitivity, length, and diameter of cocoons measured by digital slide calipers.

3.11 Short term cold preservation of cocoon, moth and egg :

Before designing preservation schedule, the rearing was conducted during adverse months namely June – July, July – August and August – September and subsequent grainage operations were done. To find out the survivability the parameters like effective rate of rearing : ERR by number which was calculated as ERR number = No. of cocoon harvested per 100 larva reared, pupal period, egg production reflected as fecundity, incubation period and hatchability were recorded.

3.11.1 Preservation of cocoons :

Cocoons were collected before adverse season from May – June commercial rearing and preserved in environmental test chamber at 5^{0}C, 7^{0}C and 10^{0}C for a period of

18 days. Effect of preservation of low temperature on pupal period, moth emergence, coupling efficacy, fecundity and hatchability were studied.

3.11.2 Preservation of adults :

Adults from the cocoon of May – June commercial rearing were taken and preserved in environmental test chamber at 5^0C, 7^0C and 10^0C for a period of 7 days and coupling efficacy, fecundity and hatchability were recorded as grainage performance.

3.11.3 Preservation of eggs :

Eggs were collected for low temperature preservation at 4^0C, 6^0C, 8^0C and 10^0C in BOD incubating 1^{st} : 24 hours , 2^{nd} : 48 hours , 3^{rd} : 72 hours and 4^{th} : 96 hours day laying for 3, 7, 12, 15 and 21 days. Simultaneously a batch of eggs was allowed to hatch in normal condition to measure delay hatching caused by low temperature preservation. Incubation period, days delay and hatchability were recorded.

3.11.4. Continuous preservation of cocoon, moth and egg :

Cocoons were collected from the commercial rearing of May – June and preserved at low temperature. Consequently after emergence of adult from preserved cocoon were preserved and simultaneously eggs laid by preserved adult were taken for preservation. The effect of continuous preservation of cocoon, adult and egg were studied.

3.12 Statistical analysis :

For better interpretation of results the experiment were laid out on various design of experiment as and when required. All the experiment were replicated thrice. Influence of season as well as host plants performance were plotted on two factor factorial Randomized Block Design : RBD . Seasons and host plant were considered as 1^{st} factor and 2^{nd} factor respectively. Manipulation of environmental factor such as different ranges of temperature, relative humidity and photoperiod as well as there different combinations were plotted in to Randomized Block Design : RBD. Synchronization of different day wise preserved male and female moths at normal and controlled temperature condition and coupling them with different combination *i.e.* T_1, T_2, T_3, T_5, T_5, ... T_{16} and the efficacy of mating hour's ranges were laid out in a

Randomized Block Design : RBD. For cocoon characterization different weight groups were considered as a treated and plotted under Randomized Block Design : RBD . On the other hand, influence of different weight groups on grainage performance were laid out in Split Plot Design, where group of male cocoon were consider as main plots and group of female cocoon were consider as sub plots. Preservation of cocoon, moth as well as egg of muga silkworm was carried during different seasons were calculated through Randomized Block Design : RBD . The preservation duration *i.e.* days with temperature ranges were analyzed through two factor factorial combinations were plotted in to Randomized Block Design (RBD), when temperature keeping on first factor where as days were consider as second factor.

The relationship between the environmental factors, intrinsic factors as well as grainage performance of larvae fed on both som and soalu were correlated. Multiple regration of the important parameters were worked out using the formula – $Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + \dots\dots\dots\dots\dots\dots + b_nx_n$. The co-efficient of determination : $R = r^2$ which is the ratio of predicted and total variance was calculated to represent the variability in dependent variable in percentage due to variation of independent variable. The significant levels were taking under consideration from 0.5 % to 0.01 % level of confidence.

CHAPTER - IV

RESULTS

4.1 Seasonal Influences on Grainage Performances of Muga Silkworm :

Rearing of muga silkworm larvae was conducted during (nine) 9 different periods in a year viz. January-March, February-March, April-May, May-June, July-August, August-September, October-November, November-December and December-February for crop production and subsequent grainage operation. As the environmental parameters like temperature, relative humidity, photoperiod and rainfall prevailing during the rearing period have effect on reproductive structure development, maturity and physiological processes attached to grainage performance of muga silkworm, the total period starting from egg hatching to subsequent egg hatching has been taken under consideration. As there present two principal host plants of muga silkworm, *i.e.* Som (*Persea bombycina* Kost.) and Soalu (*Litsea polyantha* Juss.), effect has been considered on both the two host plants.

4.1.1 Environmental factors during different seed production period of muga silkworm :

Environmental parameters taken into account to assess the seasonal influence were temperature (maximum and minimum), relative humidity (maximum and minimum), photoperiod (light and dark) and rainfall (Table 11).

Table 11. Mean Meteorological data (2003-2007)

Seasons	Temperature ^{0}C			Relative Humidity (%)			Photoperiod (h)		Rainfall (mm)
	Max.	Min.	Avg.	Max.	Min.	Avg.	Light	Dark	
February-March	23.96	15.17	19.56	72.40	57.38	64.89	12.15	11.45	57.53
April-May	27.75	21.52	24.63	76.75	71.07	73.91	12.46	11.14	164.14
May-June	33.75	29.97	31.86	83.57	76.55	80.06	13.13	10.47	506.94
July-August	34.24	30.24	32.24	85.15	78.93	82.04	13.07	10.53	725.44
August-September	30.90	27.74	29.32	79.62	74.30	76.96	12.31	11.29	381.15
Oct.-November	26.91	19.24	23.07	75.41	70.63	73.02	11.14	12.46	42.32
Nov.-December	24.14	13.97	19.05	73.02	67.65	70.33	10.47	13.13	5.77
Dec.-February	20.54	11.19	15.86	77.32	62.80	70.06	10.50	13.10	12.42
January-March	21.96	13.20	17.58	70.40	59.33	64.86	11.12	12.48	20.01

4.1.1.1 Temperature during different seed production periods :

Average maximum temperature was recorded higher during summer and rainy months. The maximum temperature during July-August was observed the highest

(34.24^{0}C) followed by May-June (33.75^{0}C). During April-May (27.75^{0}C) and August-September (30.90^{0}C) the temperature was not so high but still higher than autumn months, i.e. during October-November (26.91^{0}C). During winter months the maximum temperature observed lower and lowest being from December-February (20.54^{0}C), followed by winter to spring months (January-March : 21.96^{0}C) and spring months (February – March : 23.96^{0}C).

Average minimum temperature followed the similar trend. Average minimum temperature was recorded highest during July-August (30.24^{0}C) followed by May-June (29.97^{0}C). Autumn showed moderate minimum temperature (October-November : 19.24^{0}C). Winter months especially during December-February (11.19^{0}C) the average minimum temperature was lowest. However, during February-March, the spring month showed lower minimum temperature (15.17^{0}C) than the early winter months, November-December (13.97^{0}C).

From the average of maximum and minimum temperature, the periods can be arranged by descending order in the following order July-August > May-June > August-September > April-May > October-November > February-March > November-December > January-March > December-February.

4.1.1.2. Relative humidity during seed production period :

Average maximum RH was observed during July-August (85.15%) followed by May-June (83.57%), August-September (79.62%) and others. Lowest maximum RH was recorded during January-March (70.40%) followed by February-March (72.40%), November-December (73.02%) and others. During October-November (75.41%) and April-May (76.75%), the maximum RH was recorded around 75%.

Average minimum RH was observed during summer months when the temperature recorded very high and among them July-August (78.93%) recorded highest followed by May-June (76.55%). Lowest minimum RH was observed during spring, February-March (57.83%) followed by January-March (59.33%).

The average of relative humidity that prevailed during different periods followed the similar order as temperature excepting Some differences during winter and spring months. The order of periods in descending manner is July-August > May-June > August-September > April-May > October-November > November-December > December-February > February-March > January-March.

4.1.1.3. Photoperiod during different seed productive period :

Day length was observed highest during May-June (13 hrs. 13 min.) followed by July-August (13 hrs. 07 min.), April-May (12 hrs. 46 min.) and others.

Dark period was observed highest during November-December (13 hrs. 13 min.) followed by December-February (13 hrs. 10 min.), January-March (12 hrs. 48 min.), October-November (12 hrs. 46 min.) and others.

It was observed that day length was higher in summer and rainy months and night hours were higher during winter. During spring, February-March (L : D; 12.15 : 11.45) the light and dark period was observed almost same.

4.1.1.4. Rainfall during different seed productive period :

Highest rainfall was observed during July-August (725.44 mm.) followed by May-June (506.94 mm.) and August-September (381.15 mm.). During April-May the rainfall recorded moderate (164.14 mm.). During other periods the rainfall observed low and almost no rainfall during November-December (5.77 mm.).

From the above results on environmental parameters, it can be said that summer and rainy months were prevailed by higher temperature, humidity as well as high rainfall and longer day length. Low temperature with low humidity and longer dark period having almost no rainfall prevailed during winter months. Pleasant weather parameters were observed during autumn months *i.e.* during October-November and during spring months *i.e.* during February-March.

4.1.2. Intrinsic factors influencing seed production of muga silkworm fed on different host plants during different seasons :

Intrinsic factors influencing seed production were recorded as pupal period, emergence period, mating period, incubation period and oviposition period nourished on Som and Soalu plant separately during all the nine periods and data thus obtained were depicted in table 12 and 13.

4.1.2.1 Pupal period :

4.1.2.1.1 On Som plant :

Pupal period was recorded significantly highest during December-February (28.9 days) followed by January - March (23.7 days), November - December (21 days) and others. Significantly lowest pupal period was observed during July - August (17.6 days), May-June (17.7 days) and August-September (17.9 days) non-significant variation. There observed non-significant variation between April - May (18.00 days) and October - November (18.30 days) also.

4.1.2.1.2 On Soalu plant :

Pupal period was observed significantly highest during December-January (29.90 days) followed by January-March (23.90 days), November-December (21.80 days) and others. Lowest pupal period was observed during July-August (17.70 days), August – September (17.80 days) and May – June (18.10 days) having non-significant difference between them. There observed significant variation between April – May (18.60 days) and October – November (19.30 days).

From the results it was observed that muga silkworm larvae fed on Som plant showed shorter pupal period (20.18 days) than Soalu (20.84 days). So far as, seasons were concerned, winter seasons showed longer pupal period than summer seasons. Pupal period during autumn and spring was almost same as summer months.

4.1.2.2. Emergence period :

4.1.2.2.1 On Som plant :

Emergence periods was observed highest during July-August (4.75 min.) followed significantly by May-June (4 min.) and others. Lowest emergence period was

Table 12 Effect of seasons on intrinsic factors influencing grainage performance like pupal period, emergence period, mating period of muga silkworm, *Antheraea assama* Ww.

Seasons	Pupal Period (Days) (Avg. Male & Female)			Emergence Period (Min.) (Avg. Male & Female)			Mating Period (Hrs.)		
	Som	Soalu	Average	Som	Soalu	Average	Som	Soalu	Average
February-March	18.50	20.50	19.50	1.51	1.64	1.58	18.40	18.20	18.30
April-May	18.00	18.60	18.30	1.45	1.55	1.50	16.20	17.00	16.60
May-June	17.70	18.10	17.90	4.00	4.20	4.10	14.00	13.20	13.60
July-August	17.60	17.70	17.65	4.75	5.25	5.00	12.80	12.00	12.40
August-September	17.90	17.80	17.85	2.34	2.50	2.42	16.40	17.20	16.80
October-November.	18.30	19.30	18.80	1.42	1.47	1.45	18.80	18.40	18.60
November-December	21.00	21.80	21.40	1.35	1.40	1.38	19.60	19.80	19.70
December-February	28.90	29.90	29.40	1.13	1.30	1.22	19.00	19.20	19.10
January-March	23.70	23.90	23.80	1.52	1.70	1.61	19.00	19.00	19.00
Mean	**20.18**	**20.84**	**20.51**	**2.16**	**2.33**	**2.25**	**17.13**	**17.11**	**17.12**
CD at 5%									
Season (S)	**0.193**			**0.164**			**0.411**		
Host plant (H)	**0.410**			**0.348**			**0.873**		
Interaction (S x H)	**0.579**			**0.493**			**1.234**		

observed December - February (1.13 min.) followed non-significantly by November - December (1.35 min.). Though minimum emergence period was observed December-February but the period during January-March (1.52 min.) and February-March (1.51 min.) recorded much higher even higher than October-November (1.42 min.) and April - May (1.45) also having non-significant variation between them.

4.1.2.2.2 On Soalu plant :

Emergence period was observed highest during July-August (5.25 min.) followed significantly by May - June (4.20 min.) and others. Lowest emergence period was observed during December - February. (1.30 min.) having non-significant variation with November – December (1.40 min.), October – November (1.47 min.), February – March (1.64 min.), April – May (1.55 min.) and January – March (1.70 min.).

It was found that emergence period was shorter in the moth fed on Som than by the moth fed on Soalu though the difference was non-significant. In summer and rainy months, muga silkworm took longer time to emerge than other seasons and shorter period was taken by winter and autumn months.

4.1.2.3. Mating period :

4.1.2.3.1 On Som plant :

Highest mating period was observed during November-December (19.60 hrs.) followed significantly by December-February (19 hrs.), January-March (19 hrs.) where the variations were non-significant. October-November (18.80 hrs.) and February – March (18.40 hrs.). Lowest mating period was observed during July-August (12.80 hrs.) followed non-significantly by May-June (14 hrs.).

4.1.2.3.2. On Soalu plant :

Highest mating period was recorded during November-December (19.80 hrs.) followed non-significantly by December - February (19.20 hrs.) and January – March (19.00) and significantly by others. Lowest mating period was observed during July-August (12.00 hrs.) followed by May-June (13.20 hrs.) having non-significant variation.

Mating period observed more or less similar in Som and Soalu where the variations were non-significant. During summer months mating period was shorter than the winter months.

4.1.2.4. Oviposition period :

4.1.2.4.1 On Som plant :

Oviposition period observed significantly highest during October-November (6.8 days) followed by November-December (6.6 days), February-March (6 days), having non-significant variation between the two and significantly by others. Lowest oviposition period was observed during July-August (4 days) followed significantly by May-June (4.4 days), August-September (4.6 days) having non-significant variation and by others. However winter months *i.e.* December-February (5.6 days) and January-March (5.2 days) showed non-significant difference.

4.1.2.4.2 On Soalu plant :

Oviposition period on Soalu followed the similar trend as on Som. Highest oviposition was observed during October-November (6 days) followed non-significantly by November-December (5.8 days), February-March (5.4 days) and significantly others and lowest being from July-August (3.8 days), May-June (4 days) and August-September (4.2 days) having non-significant variation.

Oviposition period observed non-significantly longer when larvae fed on Som plant (5.38 days) than Soalu (4.93 days). Moreover, irrespective of host plant shorter oviposition period was observed in summer months.

4.1.2.5. Incubation period :

4.1.2.5.1 On Som plant :

Highest incubation period was observed during December-February (11.8 days) followed non-significantly by January-March (11.4 days) and significantly by others. Incubation period during October-November (8.2 days) and November-December (8.6 days) recorded nearly three days less than the highest incubation period. Lowest incubation period was observed during July-August (7 days) followed by May-June (7.2 days) having non-significant difference between them. Incubation period recorded same (7.4 days) during April-May and August-September, slightly lower than the incubation period during February-March (7.8 days) having non-significant variation.

Table 13 Effect of seasons on intrinsic factors influencing grainage performance like oviposition period, incubation period of muga silkworm, *Antheraea assama* Ww.

Seasons	Oviposition Period (Days)			Incubation Period (Days)		
	Som	Soalu	Average	Som	Soalu	Average
February-March	6.0	5.4	5.7	7.80	8.40	8.10
April-May	5.8	5.0	5.4	7.40	7.50	7.45
May-June	4.4	4.0	4.2	7.20	7.20	7.20
July-August	4.0	3.8	3.9	7.00	7.00	7.00
August-September	4.6	4.2	4.4	7.40	7.60	7.50
October-November	6.8	6.0	6.4	8.20	8.60	8.40
November-December	6.6	5.8	6.2	8.60	9.00	8.80
December-February	5.6	5.2	5.4	11.80	11.80	11.80
January-March	5.2	5.0	5.1	11.40	10.60	11.00
Mean	**5.4**	**4.9**	**5.2**	**8.53**	**8.63**	**8.58**
CD at 5%						
Season (S)	**0.257**			**0.207**		
Host plant (H)	**0.545**			**0.440**		
Interaction (S x H)	**0.771**			**0.623**		

4.1.2.5.2 On Soalu plant :

Highest incubation period was observed during December-January (11.80 days) followed significantly by January-March (10.60 days) and others. No significant differences were observed between November-December (9.00 days), October-November (8.60 days) and February-March (8.40 days). Significantly lowest incubation period was observed during July-August (7 days) having non-significant differences with August-September (7.60 days), April-May (7.50 days) and May-June (7.20 days).

Incubation period was observed shorter in the eggs fed on Som plant (8.53 days) than on Soalu plant (8.63 days) having non-significant variation and winter months had prolonged incubation period irrespective of leaves of different plants fed.

4.1.3. Seed production of muga silkworm fed on different host plants during different seasons :

Seed production parameters taken into account were potential fecundity, realised fecundity, egg retention inside female body and hatching percentage on Som and Soalu plant during nine different periods and data thus obtained were depicted in table 14 and 15.

Table 14 Effect of seasons on grainage performance like Potential fecundity, Realised fecundity of muga silkworm, *Antheraea assama* Ww.

Season	Potential Fecundity (PF)			Realised Fecundity					
				Total (RF)			upto 3 days (3DRF)		
	Som	Soalu	Avg.	Som	Soalu	Avg.	Som	Soalu	Avg.
February-March	240.00	223.00	231.50	238.00	218.00	228.00	204.00	181.00	192.50
April-May	254.40	242.00	248.20	251.20	238.40	244.80	216.80	184.60	200.70
May-June	235.20	212.60	223.90	230.00	198.00	214.00	204.40	164.40	184.40
July-August	235.40	208.80	222.10	188.00	159.60	173.80	162.80	133.00	147.90
August- September	241.80	214.00	227.90	230.20	202.40	216.30	179.80	159.60	169.70
October- November	285.60	267.60	276.60	283.80	265.60	274.70	222.60	213.00	217.80
November-December	250.00	235.20	242.60	245.00	232.40	238.70	204.40	172.20	188.30
December-February	208.80	218.20	213.50	193.00	208.40	200.70	151.80	149.80	150.80
January-March	203.80	217.60	210.70	200.00	205.60	202.80	146.80	148.80	147.80
Mean	**239.44**	**226.55**	**233.00**	**228.80**	**214.26**	**221.53**	**188.20**	**167.37**	**177.79**
CD at 5%									
Season (S)	**6.48**			**6.88**			**5.50**		
Host plant (H)	**3.05**			**3.25**			**2.59**		
Interaction (S x H)	**9.16**			**9.73**			**7.78**		

4.1.3.1. Potential fecundity

4.1.3.1.1 On Som plant :

Signification variation was observed among the seasons. Significantly highest potential fecundity was recorded during October-November (285.60) followed by April-May (254.40) and November - December (250.00) having non-significant variation between the two and significantly by others. It was found nearly the same potential fecundity during February - March and August - September (240.00 and 241.80 respectively) and also during May-June and July-August (235.20 and 235.40 respectively) having non-significant variation between those four periods. During December-February the potentiality was the lowest (208.80) followed by that in January-March (203.80).

4.1.3.1.2 On Soalu plant :

Significant variation was observed among the seasons. Significantly highest potential fecundity was recorded during October-November (267.60) followed significantly by April-May (242.00) and November-December (235.20) having non-significant variation between those two periods and by others. Lowest potential fecundity was observed during July-August (208.80) having non-significant difference with May-June (212.60) and August - September (214.00).

Potential fecundity was observed significantly higher in moth fed on Som leaves (239.44) than on Soalu leaves (226.55) irrespective of seasons. However, from the seasonal stand point October-November (276.60) and April-May (248.20) showed better fecundity having significant difference between them as well as than other periods.

4.1.3.2. Realised fecundity :

4.1.3.2.1 On Som plant :

Total (RF) : Realised fecundity was also observed significantly highest during October-November (283.80) followed by April-May (251.20) and November-December (245.00) having non-significant variation and by others. The lowest realised fecundity was observed during July-August (188.00) followed non-significantly by December-February (193.00). During January-March realised fecundity (200.00) was also low.

However, during May-June & August-September, realised fecundity was same (230.00 and 230.20 respectively).

Upto three days (3DRF) : However, usual recommendation regarding effective collection of eggs is up to three days to minimize the length of rearing and to synchronize the mating. Data were recorded up to three days which reflected the same trend like realised fecundity i.e. the best during October-November (222.60) followed by that April-May (216.80) having non-significant variation and the lowest during January-March (146.80) and December – February (151.80) having non significant variation.

4.1.3.2.2 On Soalu plant :

Total (RF) : Realised fecundity was also observed significantly higher in October-November (265.00) followed significantly by April-May (238.40) and November-December (232.40) having non-significant variation between them and by others. Lowest fecundity was observed during July-August (159.00).

Upto three days (3DRF) : Realised fecundity upto 3 days was recorded and the highest fecundity was observed during October-November (213.00) followed significantly by February-March (181.00) & April-May (184.00) having non-significant variation among the two and by others. Lowest realised fecundity upto 3 days was observed during July-August (133.00).

Realised fecundity followed the similar trend as potential fecundity. Som (RF : 228.80 and 3DRF : 188.20) performed better than Soalu (RF : 214.26 and 3DRF : 167.37) and among the seasons October - November (RF : 274.70 and 3DRF : 117.80) was the best followed by April – May (RF : 244.80 and 3DRF : 200.70) and February-March (RF : 228.00 and 3DRF : 192.50). During the summer and rainy months, performance was poor.

4.1.3.3. Egg retention :

4.1.3.3.1 On Som plant :

Egg retention was significantly very high during July-August (47.40) followed by August-September (11.60) and by others. During October-November (1.80) and February - March (2.00) the retention inside female body was almost nil.

4.1.3.3.2 On Soalu plant :

Egg retention during July-August (49.20) was significantly very high over other seasons. Egg retention during October-November was observed very little (2.00) followed non-significant by November-December (2.80) and April-May (4.00) and significantly by others.

Table 15 Effect of seasons on grainage performance like Egg retention, Hatching percentage of muga silkworm, *Antheraea assama* Ww.

Seasons	Egg Retention (ER)			Hatching Percentage (HP)		
	Som	Soalu	Avg.	Som	Soalu	Avg.
February-March	2.00	5.00	3.50	97.18	91.29	94.24
April-May	3.20	4.00	3.60	44.79	40.11	42.45
May-June	5.20	14.60	9.90	20.88	14.84	17.86
July-August	47.40	49.20	48.30	6.24	5.26	5.75
August-September	11.60	11.60	11.60	63.03	57.06	60.05
October-November	1.80	2.00	1.90	98.87	96.40	97.64
November-December	5.00	2.80	3.90	97.29	95.74	96.52
December-February	7.80	9.80	8.80	97.82	92.03	94.93
January-March	3.40	12.00	7.70	98.20	96.00	97.10
Mean	**9.71**	**12.33**	**11.02**	**69.37**	**65.41**	**67.39**
CD at 5%						
Season (S)	**2.54**			**1.66**		
Host plant (H)	**1.20**			**0.78**		
Interaction (S x H)	**3.60**			**2.35**		

Egg retention in female body was observed a little bit higher in Soalu (12.33) than Som (9.71) and during July – August (48.30) the retention was maximum irrespective of leaves.

4.1.3.4 Hatching percentage :

4.1.3.4.1 On Som plant :

Hatching percentage was observed the highest during October-November (98.87%) having non significant difference with January-March (98.20%), December-February (97.82%), November - December (97.29%) and February - March (97.18%). During May-June, the hatching percentage was poor (20.88%) and during July-August almost no egg hatched (6.24%).

4.1.3.4.2 On Soalu plant :

Hatching percentage was observed higher during October-November (96.40%) having non-significant difference with January-March (96.00) and November-December (95.74%) and having significant difference with others. Lowest hatching percentage was observed during July-August (5.26%) followed by May-June (14.84%) which were reflected almost no hatching.

Larvae fed on Som showed better hatching percentage (69.37%) than Soalu (65.41). Among season during summer months, the hatching percentage was very poor.

4.1.4 Co-relation Studies :

Co-relation Studies of environmental factors namely temperature (average), relative humidity (average) and photoperiod (light period) and intrinsic factors namely pupal period, emergence period, mating period, oviposition period and incubation period with the seed production parameters namely potential fecundity, realized fecundity, realized fecundity upto 3 days and hatching percentage were done considering seed crop rearing seasons (April – May and August – September) and commercial crop rearing seasons (May – June and October – November) as seasonal influences on both the host plants (Som and Soalu) separately and on average.

Table 16 Correlation Coefficient of environmental factors on intrinsic factor of Som plant

	Pupal Period	Emergence Period	Mating Period	Oviposition Period	Incubation Period
Temperature	-.093	0.47	-0.75	-0.92	-0.94
Relative Humidity	-0.25	0.18	-0.77	-0.59	-0.19
Photoperiod L	-0.99***	0.78	-0.73	-0.90	-0.97*

* Significant at 5% level of confidence
*** Significant at 0.05% level of confidence

4.1.4.1 On Som plant :

4.1.4.1.1 Environmental factors with intrinsic factors :

Temperature, relative humidity and light period had negative co-relation with pupal period, mating period and oviposition period while had positive co-relation with emergence period. Light period had significant negative co-relation with incubation period at 5% level and had highly significant negative co-relation with pupal period at 0.05% level (Table 16).

4.1.4.1.2 Environmental factors with seed production parameters :

Temperature, relative humidity and light period had negative co-relation with fecundity and hatchability. Temperature showed highly significant negative co-relation (1% level) with potential fecundity and very high negative co-relation (0.05% level) with realized fecundity. Light period showed highly significant negative co-relation (1% level) with hatching percentage (Table 17).

Table 17 Correlation Coefficient of environmental factors on grainage performance of Som plant

	PF	RF	3DRF	Hatchability
Temperature	-0.98**	-0.99***	-0.77	-0.81
Relative Humidity	-0.42	-0.48	-0.71	-0.08
Photoperiod L	-0.94	-0.89	-0.41	-0.98**

* Significant at 5% level of confidence
*** Significant at 0.05% level of confidence

4.1.4.1.3 Intrinsic factors with seed production parameters :

Except emergence period, all the intrinsic factors showed positive co-relation with fecundity and hatchability. Pupal period had significant positive co-relation with potential fecundity and hatching percentage. Oviposition period had significantly positive co-relation (5% level) with potential fecundity (Table 18).

Table 18 Correlation Coefficient of intrinsic factor on grainage performance of Som plant

	PF	RF	3DRF	Hatchability
Pupal Period	0.97*	0.93	0.49	0.97*
Emergence Period	-0.58	-0.48	0.10	-0.84
Mating Period	0.77	0.76	0.54	0.67
Oviposition Period	0.95*	0.93	0.62	0.85
Incubation Period	-	-	-	0.93

* Significant at 5% level of confidence

4.1.4.2 On Soalu plant :

4.1.4.2.1 Environmental factors with intrinsic factors :

Except emergence period all the intrinsic factors had negative co-relation with environmental factors. Significant negative co-relation at 5% level was observed between temperature and pupal period (Table 19).

Table 19 Correlation Coefficient of environmental factors on intrinsic factor of Soalu plant

	Pupal Period	Emergence Period	Mating Period	Oviposition Period	Incubation Period
Temperature	-0.97*	0.51	-0.82	-0.57	-0.78
Relative Humidity	-0.52	0.20	-0.72	-0.03	-0.18
Photoperiod L	-0.76	0.78	-0.79	-0.86	-0.86

* Significant at 5% level of confidence

4.1.4.2.2 Environmental factors with seed production parameters :

Environmental factors showed negative co-relation with fecundity and hatchability. Temperature had significant negative co-relation (0.5% level) with potential fecundity and realized fecundity upto three days. Temperature also showed significant negative co-relation (5% level) with realized fecundity. Photoperiod (light) showed highly significant (0.5% level) negative co-relation with hatchability (Table 20).

Table 20 Correlation Coefficient of environmental factors on grainage performance of Soalu plant

	PF	RF	3DRF	Hatchability
Temperature	-0.99***	-0.98*	-0.99***	-0.82
Relative Humidity	-0.61	-0.69	-0.59	-0.10
Photoperiod L	-0.85	-0.85	-0.84	-0.99***

* Significant at 5% level of confidence
** Significant at 0.05% level of confidence

4.1.4.2.3 Intrinsic factors with seed production parameters :

Pupal period showed significant (at 5% level) positive co-relation with fecundity. All other factors except emergence period showed negative co-relation with fecundity and hatchability (Table 21).

From the correlation studies, it has been noticed that the environmental factors and intrinsic factors have influence on seed production of which temperature has strong negative influence on fecundity and light period has strong negative influence on hatchability. Temperature and photoperiod have strong negative correlation with pupal period and oviposition period respectively slowly the influence of environmental factors on intrinsic factor also. Intrinsic factors influenced the seed produced, particularly pupal period had strong negative correlation with fecundity and oviposition period has strong negative correlation with hatchability.

Table 21 Correlation Coefficient of intrinsic factor on grainage performance of Soalu plant

	PF	RF	3DRF	Hatchability
Pupal Period	0.96*	0.95*	0.98*	0.66
Emergence Period	-0.52	-0.55	-0.49	-0.83
Mating Period	0.88	0.91	0.81	0.74
Oviposition Period	0.54	0.56	0.48	0.92
Incubation Period	0.68	0.64	0.78	0.85

* Significant at 5% level of confidence

4.1.5 Seasonal influence on day wise egg laying and hatching :

After rearing of five different periods namely February – March, April – May, June – July, August – September and October – November, the cocoons were taken irrespective of host plant feeding. After moth emergence natural coupling was allowed and females laid eggs on *kharika* and day wise collection of eggs was maintained.

4.1.5.1 Effect of season on grainage parameters :

During February-March, April – May, June-July, August-September and October-November the key grainage parameters namely potential fecundity, realized fecundity and hatchability were recorded (Table 22).

Highest potential fecundity was recorded during October-November (280.00) followed significantly by April - May (248.00) and by others, lowest being from June – July (217.00) similarly, egg laying (realized fecundity) was significantly highest during October-November (278.00) followed by April - May (245.00) and others, lowest being from June-July (170.00).

Table 22 Seasonal influence on grainage performance of muga silkworm, *Antheraea assama* Ww.

Season	Potential Fecundity (No.)	Realized fecundity (No.)	Hatchings (No.)	Hatching %
Feb.-Mar.	235.00	230.00	216.20	94.00
April-May	248.00	245.00	104.00	42.45
June-July	217.00	170.00	12.00	7.06
Aug.-Sept.	225.00	216.00	130.00	60.19
Oct.-Nov.	280.00	278.00	266.00	95.68
CD at 5%	**3.30**	**2.87**	**1.89**	**0.71**

Regarding hatchability, hatching number was significantly highest during October-November (266.60) where 95.68% hatching was observed followed by February - March (218.20) having 94.00 hatching percentage. During June-July, hatchability was very poor (number 12.00 and percentage 7.21%).

From overall observation it was found that October-November was best performing grainage season for egg laying and hatchability. Though egg laying was better during April – May, hatchability was better during February – March followed by August – September.

4.1.5.2 Day wise seasonal egg laying and hatching :

4.1.5.2.1 Egg laying :

4.1.5.2.1.1 Seasonal influence :

October-November was found most productive (278.00) and followed significantly by April – May (245.00) and others. Significantly worst performance was observed during July-August (170.00) (Table 23).

4.1.5.2.1.2 Day-wise effect :

Significant differences were observed among the egg laying of different days. A sharp significant decreasing trend was recorded in any season. Highest egg laying was recorded on 1st day followed significantly by all other days. (Table 23).

Table 23 Different day egg laying of muga silkworm, *Antheraea assama* Ww. in different seasons.

Seasons	1st day	2nd day	3rd day	4th day	5th day	6th day	Total
Feb-Mar	89.38	74.38	29.95	23.00	9.20	4.09	**230.00**
April-May	111.70	61.76	31.60	23.52	16.39	-	**245.00**
June-July	49.20	46.40	34.70	23.90	16.40	-	**170.60**
Aug-Sep	94.78	55.92	30.39	25.21	9.65	-	**216.00**
Oct-Nov	137.40	65.72	31.66	22.33	13.37	7.52	**278.00**

CD at 5%	
Season	1.94
Different Day	1.10
Season x Different day	2.54

4.1.5.2.1.3 Effect of season & day :

Significantly highest egg laying was observed on 1st day during October-November (137.40) followed by 1st day of April - May (111.70), August – September (94.78) and February – March (89.38). On 2nd day best performance was observed during February. -March (74.38) followed by October – November (65.72), April – May (61.76) and others. Non-significant production of egg was observed on 3rd day (29.95 – 31.66) and 4th day (22.33 – 23.90) except on 3rd day during June-July (34.70) and on 4th day during August – September. On 5th day, highest laying was observed during June – July (16.40) followed non significantly by April – May (16.39) and significantly by October – November (13.37) and others. During April – May, June – July and August – September egg laying was completed within fifth day. Only during October – November and February – March layings were obtained on 6th day (8.62 and 4.09) also.

4.1.5.2.2 Hatching:

4.1.5.2.2.1 Effect of season :

Almost no hatching was observed during June-July (12.00). Hatching during October-November was found significantly highest (266.60) followed by February – March (216.20) and others (Table 24).

4.1.5.2.2.2 Effect of day :

A similar decreasing trend was observed like egg laying. Hatching percentage was observed highest during 1st day and decreased as days progressed (Table 24).

Table 24 Hatching of egg laid by muga silk worm *Antheraea assama* Ww. on different day in different season.

Season	1^{st} day	2^{nd} day	3^{rd} day	4^{th} day	5^{th} day	6^{th} day	Total
Feb.-Mar	86.79	70.74	27.64	20.39	7.54	3.10	**216.20**
April-May	50.80	25.47	13.05	8.86	5.82	-	**104.00**
June-July	7.00	5.00	-	-	-	-	**12.00**
Aug.-Sept.	62.93	33.00	15.32	12.10	4.65	-	**130.00**
Oct-Nov.	135.80	65.20	30.80	21.80	11.40	1.60	**266.60**

CD at 5%

Season	1.53
Different Day	1.59
Season x Different day	2.41

4.1.5.2.2.3 Effect of season and day :

Significantly best hatching was observed on 1^{st} day laying during October - November (135.80) followed by February - March (86.79), August - September (62.93) and others. Hatching of 2^{nd} day laying during February – March (70.74) and October – November (65.20) was significantly higher than the hatching of 1st day laying of August – September (62.93), April – May (50.80) and June – July (7.00). Hatching performance of 3rd day onward laying were better during October – November and February – March where the performances of October – November were better than February – March except for the 6th day. (Table 24).

4.1.5.3 Percentage of egg laying and hatching in different days:

During 1^{st} day, egg laying percentage was highest in any season and except June-July it was significantly higher than other days. In June-July, percentage of egg laying was more or less same in 1^{st} and 2^{nd} day. Nearly 85% eggs were laid during first three days in any season except June-July when it was around 75%. (Table 25).

Hatching percentage was found very poor during July-August. During October-November hatching of first four days eggs were more than 90%, that of fifth day it was 85.27%. During February-March hatching percentage of first three days eggs was also above 90% and that of next two days were above 80%. However, during August-September, 66.40% eggs of 1^{st} day were hatched, 59.01% eggs of second day were hatched and it was around 50 % for rest of the days. During April – May, the hatching

Table 25 Percentage of egg laying and hatching of muga silkworm *Antheraea assama* Ww. in different day during different season

Seasons	1st day		2nd day		3rd day		4th day		5th day		6th day	
	Lay-ing (%)	Hatch-ing (%)	Lay-ing (%)	Hatch-ing (%)	Lay-ing (%)	Hatch-ing (%)	Lay-ing (%)	Hatch-ing (%)	Lay-ing (%)	Hatch-ing (%)	Lay-ing (%)	Hat ching (%)
Feb-Mar.	38.86	97.10	32.34	95.11	13.02	92.29	10.00	88.65	4.00	81.96	1.78	75.79
Apr.-May	45.60	45.48	25.21	41.24	12.90	41.30	9.60	37.67	6.69	35.50	0.00	0.00
June-July	28.84	14.23	27.20	10.78	20.30	0.00	13.88	0.00	9.65	0.00	0.00	0.00
Aug-Sept.	43.88	66.40	25.89	59.01	14.07	50.41	11.67	47.99	4.47	48.19	0.00	0.00
Oct-Nov.	49.42	98.83	23.64	99.20	11.38	97.28	8.03	97.63	4.81	85.27	2.70	21.28

CD at 5%	Egg Laying	Hatching
Season	**1.58**	**1.60**
Different Day	**1.61**	**1.65**
Season x Different day	**3.92**	**2.95**

percentage was below August – September where only 41 – 45 % eggs were hatched from first 3 days and performance of the rest of the days were even more poor.

4.2. Manipulation of abiotic factors to standardize the optimum combination responsible for seed production with higher hatchability :

March – May and August – October are the two critical period for commercial rearing of muga silkworm during May – June and October – November respectively. Seed cocoons obtained from seed crop rearing during March – April were subjected to be emerged and after mating, the eggs were incubated for hatching during April – May for May – June commercial rearing. Likewise, seed cocoons from August – September rearing gave the hatched larva during September – October for subsequent commercial rearing during October – November. Manipulation of temperature, humidity and photoperiod during April – May and September – October were done to record the hatchability of eggs.

4.2.1 Manipulation of Temperature :

Five temperature ranges were taken under consideration namely T_1 (15 ^{0} C), T_2 (20 ^{0} C), T_3 (25 ^{0} C), T_4 (30 ^{0} C), and T_5 (35 ^{0} C).

Table 26 Effect of temperature manipulation on hatchability of muga silkworm *Antheraea assama* Ww. during April – May

April-May	Hatching No (HN)	Hatching % (HP)
T_1	117.67	46.97
T_2	125.80	50.15
T_3	147.89	59.03
T_4	109.68	43.88
T_5	39.05	15.71
Mean	**108.02**	**43.15**
Control (26.65^0 C)	112.43	44.79
S Em (±)	0.61	0.22
CD (P = 0.05)	**2.13**	**0.75**

Where, T_1= 15 ^{0}C, T_2= 20 ^{0}C, T_3= 25 ^{0}C, T_4= 30 ^{0}C, T_5= 35 ^{0}C

4.2.1.1 Manipulation of temperature during April – May :

T_1, T_2 and T_3 showed higher hatching number (HN) and hatching percentage (HP) than control, but T_4 and T_5 failed to perform better. In T_3, HN and HP were 147.89 and

59.03 % respectively which were significant best among the treatments followed by T_2 (125.80 and 50.15% for HN and HP respectively) and T_1 (117.67 and 46.97 % for HN and HP respectively) T_5 performed worst having HN of 39.05 and HP of 15.71 % which was far below than the control where hatching number and hatching percentage were 112.43 and 44.79 % respectively and the temperature was 26.65^{0}C (Table 26).

4.2.1.2. Manipulation of temperature during August – September :

T_3 showed 68.67% hatching with 157.31 number of hatched eggs which was best among the treatments and much higher than the control (HN 144.97 and HP 63.03 %). T_3 was followed by T_2 (HN 132.85 and HP 57.92 %). Unlike April - May situation, all other treatments (T_1, T_4 and T_5) failed to perform even like control (HN, HP 144.97, 63.03 and the temperature 28.92^{0}C), worst being from T_5 where HN was 70.00 and HP was 30.67 %. (Table 27).

It was recorded that the performance of T_3 (25 ^{0} C) was best during both the seasons followed by T_2 (20 ^{0} C) with reference to the prevailed temperature of 26.65 ^{0} C during April – May and of 28.92 ^{0} C during August – September.

Table 27 Effect of Temperature manipulation on hatchability of muga silkworm, *Antheraea assama* Ww. during August – September

Aug-Sept	Hatching No (HN)	Hatching % (HP)
T_1	116.92	51.07
T_2	132.85	57.92
T_3	157.31	68.67
T_4	133.21	58.01
T_5	70.00	30.67
Mean	**122.04**	**53.27**
Control (28.92^0 C)	144.97	63.03
S Em (±)	0.39	0.26
CD (P = 0.05)	**1.28**	**0.68**

Where, T_1= 15 ^{0}C, T_2= 20 ^{0}C, T_3= 25 ^{0}C, T_4= 30 ^{0}C, T_5= 35 ^{0}C

4.2.2 Manipulation of Relative humidity (RH) :

Four treatments were taken for present experiment namely R_1 (65%), R_2 (75%), R_3 (85%) and R_4 (90%).

4.2.2.1 Manipulation of RH during April-May :

During April-May, the normal RH was 68%. Among the treatments R_1 and R_2 only performed better than the control (HN 112.43 and HP 44.79%) and R_2 performed best (119.14 HN and 48.21% HP) followed significantly by R_1 (HN 111.62 and HP 45.01%). Worst performance was obtained from R_4 where hatching no. was 80.53 and the hatching percentage was 32.38% (Table 28).

Table 28 Effect of Relative Humidity manipulation on hatchability of muga silkworm *Antheraea assama* Ww. during April – May

April-May	Hatching No (HN)	Hatching % (HP)
R_1	111.62	45.01
R_2	119.14	48.21
R_3	19.20	40.16
R_4	80.53	32.38
Mean	**102.62**	**41.44**
Control (68%)	112.43	44.79
S Em (±)	0.73	0.26
CD (P = 0.05)	**2.48**	**1.00**

Where, R_1= 65% RH, R_2= 75% RH, R_3= 85% RH, R_4 >90% RH

4.2.2.2 Manipulation of RH during August-September :

During this period, the normal RH was 77.5% and only R_1 and R_2 showed significantly better performance than control (HN 144.97 and HP 63.03%) and the rest were below the level

Table 29 Effect of Relative Humidity manipulation on hatchability of muga silkworm *Antheraea assama* Ww. during August – September

Aug-Sept	Hatching No (HN)	Hatching % (HP)
R_1	137.15	60.02
R_2	145.00	73.36
R_3	129.09	56.33
R_4	98.07	42.93
Mean	**127.33**	**55.66**
Control (77.5%)	144.97	63.03
S Em (±)	1.12	0.56
CD (P = 0.05)	**3.52**	**1.62**

Where, R_1= 65% RH, R_2= 75% RH, R_3= 85% RH, R_4 >90% RH of control. R_2 performed best where HN was 145.00 and HP was 63.36% followed significantly by R_1 where HN was 137.15 and HP was 60.02%. Significantly lowest HN (98.07) and HP (42.93%) were obtained from R_4 (Table 29).

Among all the relative humidity regimes the best performance was obtained from R_2 (75%) followed by R_1 (65%) during both the seasons.

4.2.3 Manipulation of temperature and relative humidity :

The combination of all the five temperature regimes and four relative humidity regimes were tested for incubation period, hatching duration and average hatching percentage during both the seasons.

4.2.3.1 During April-May :

Incubation period and hatching duration were inversely proportional to the rise of temperature. It was observed that there was steady and significant increase in the hatching percentage along with the rise in temperature from 15°C (T_1) to 25°C (T_3), but a declining trend on hatchability was observed from 30°C (T_4) to 35°C (T_5). The hatching percentage was significantly impaired at 35°C (T_5) (Table 30).

When different humidity regimes under individual temperature treatment were compared, it was observed that humidity regimes had relatively much less effect on the incubation period and hatching duration except in lower temperature (15°C and 20°C) where higher humidity i.e. 85% (R_3) and above 90% (R_4) showed shorter incubation period. A significantly improved hatchability was observed between the treatments 65% (R_1) and 75% (R_2) in 20°C to 30°C temperature and in other cases the hatchability decreased. However, 25°C (T_3) temperature with 75% RH (R_2) proved to be the best temperature and humidity regimes for hatching of muga silk eggs (73%) followed by 25°C (T_3) temperature with 85% RH (R_3) (65%) and 25°C temperature (T_3) with 65% RH (R_1) (63%).

4.2.3.2 During August-September :

Incubation period and hatching duration were inversely proportional to the rise of the temperature. During August-September also, it was observed that there was a steady and significant increase in the hatching percentage with the rise of the temperature from 15°C (T_1) to 25°C (T_3) but a declining trend on hatchability was observed from 30°C (T_4) to 35°C (T_5) (Table 31).

When different humidity regimes under individual temperature treatment were compared, it was observed that incubation period and hatching duration were not much influenced by relative humidity. However, significant increase of hatching percentage was observed from 65% (R_1) to 75% (R_2) and then significant declining trend was observed from 85% (R_3) to above 90% (R_4).

25°C temperature (T_3) with 75% RH (R_2) showed 85% hatching percentage which recorded highest among the treatments during August-September followed significantly by T_3 x R_3 (80%), T_3 x R_1 (75%) and T_2 (20°C temperature) with 75% RH (R_2) (72%).

Overall observation reflected that hatching percentage was better during August-September. Regarding manipulation, 20°C with 75% RH and 25°C with 65% RH, 75% RH and 85% RH significantly improved the hatching percentage during both the seasons.

4.2.3.3 Rate of embryonic development :

Rate of embryonic development and its relation to different incubation temperatures (as influenced much higher than relative humidity) were depicted in figure 3 for April-May, figure 4 for August-September and figure 5 for average of seasons.

It was revealed from figure 3, figure 4 and figure 5 that incubation of eggs at lower temperature below room/environmental temperature retarded the rate of embryonic development resulting in prolonged incubation period. With the fall of temperature, the development rate gradually decreased from 12.50% of control (room temperature) to 4.88% at 15°C during April-May, from 14.29% of control (room temperature) to 4.60% at 15°C during August-September and reversely, the incubation period increased gradually from 7 days to 21 days during April-May and from 7 days to 22 days during August-September. Incubation of eggs at higher temperature above room/environmental temperature though accelerated the rate of embryonic development and thereby shortened the period of incubation, but adversely affected the hatchability of eggs.

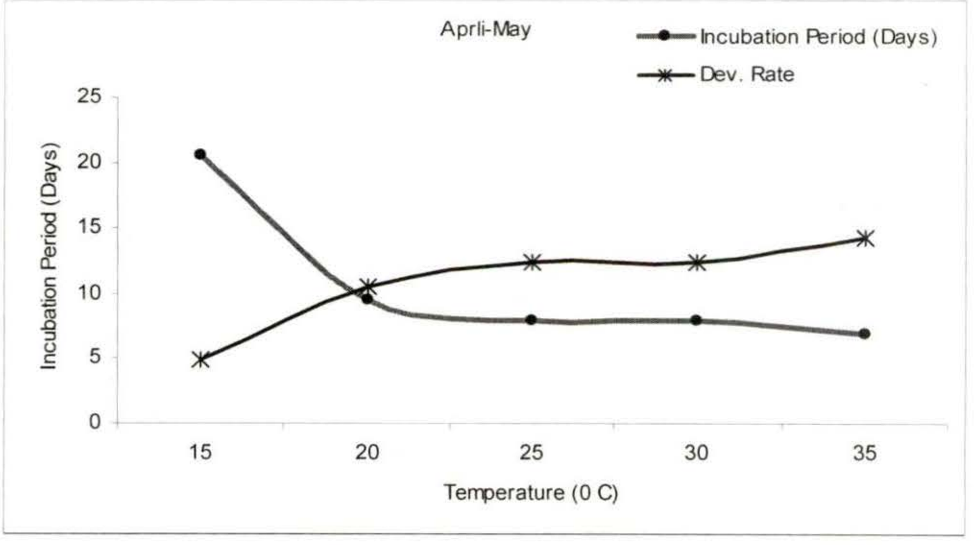

Figure 3 Rate of embryonic development of muga silkworm *Antheraea assama* Ww. under different temperature regimes during April – May

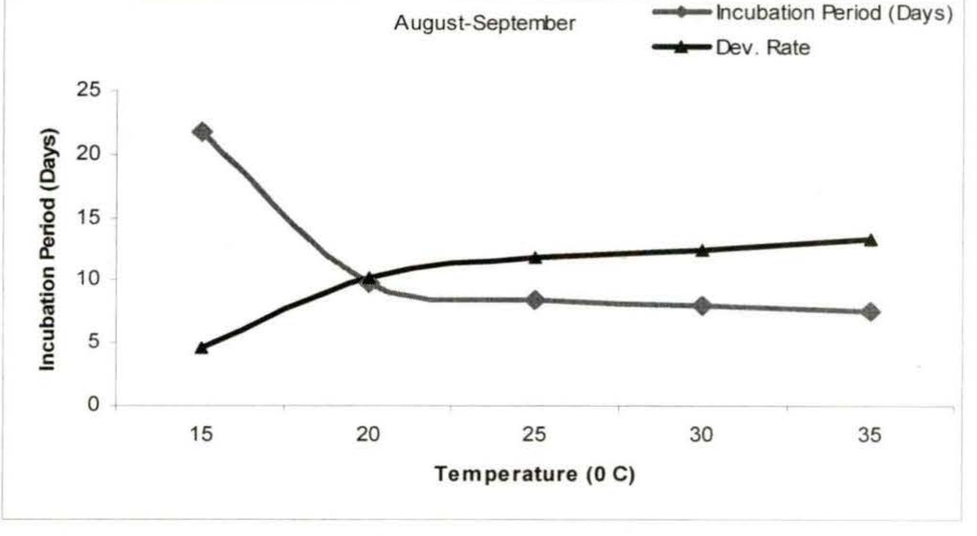

Figure 4 Rate of embryonic development of muga silkworm *Antheraea assama* Ww. under different temperature regimes during August - September

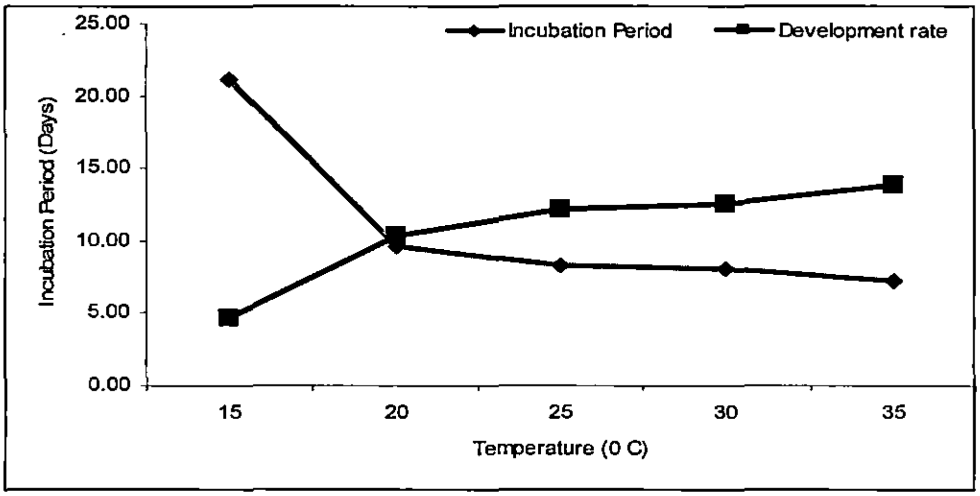

Figure 5 Average rate of embryonic development of muga silkworm *Antheraea assama* Ww. of both the season under different temperature regimes

4.2.4 Manipulation of temperature, humidity and photoperiod :

Hatching percentage at 25°C with 65% RH, 25°C with 75% RH and 25°C with 85% RH during April-May and at 20°C with 75% RH, 25°C with 65% RH, 25°C with 75% RH and 25°C with 85% RH during August-September were observed with 5 photoperiod regimes namely 6L, 9L, 12L, 15L and 18L condition and data thus obtained were depicted in Table 30 for April-May and Table 33 for August-September.

4.2.4.1 During April-May :

The room temperature, relative humidity and photoperiod during this season (control) were 26.65°C, 68% and 12.45L respectively and the hatching percentage was recorded 44.79%. After manipulation of all the environmental factors the hatching percentage was improved significantly over control in all treatments. The improvement of hatching percentage was noticed significantly with the increase in light period from 6L to 18L condition. The highest hatching percentage in 25°C with 65% RH condition was observed 69.93%, in 25°C with 75% RH condition it was 81.07% and in 25°C with 85% RH condition it was 74.01% which were in 18L light condition. However, the highest hatching percentage among the treatments considered was observed in 25°C with 75% RH and 18L condition and the hatching percentage was 81.07% (Table 32).

Table 32 Effect of temperature, Relative Humidity and Photoperiod manipulation on hatchability of muga silkworm *A. assama* Ww. during April – May.

Temperature & RH / Photoperiod (L)	25 ^{0}C+65%	25 ^{0}C+75%	25 ^{0}C+85%
6L	61.49	62.98	62.18
9L	64.70	68.06	66.25
12L	67.30	74.94	70.77
15L	69.49	77.54	72.90
18L	69.93	81.07	74.01
Mean	**66.58**	**72.92**	**69.22**
S Em (±)	0.02	0.05	0.03
CD (P = 0.05)	**0.08**	**0.16**	**0.11**

Control : 26.65 ^{0} C (Temp.)
68 % (RH)
12.45 L (Day length)

4.2.4.2. During August-September :

The room temperature, relative humidity and photoperiod during this season (control) were 28.92°C, 77.5% and 12.40L respectively and the hatching percentage was recorded 63.03%. After manipulation of all the environmental factors the hatching percentage was improved significantly over control in all the treatments except in 20°C with 75% and 6L condition where the hatching percentage was slightly lower (61.58%) than the control (63.03%). The improvement of hatching percentage was noticed significantly with the increase in light period from 6L to 18L condition. The highest hatching percentage in 25°C with 75% RH was observed 76.48%, in 25°C with 65% RH condition it was 83.83%, in 25°C with 75% RH condition it was 92.97% and in 25°C with 85% RH it was 91.54% which were in 18L condition. However, the highest hatching percentage among the treatments was observed in 25°C with 75% RH at 18L condition which was 92.97%.

Overall observation from the results reflected that the hatching percentage was significantly improved in both the seasons after manipulation of temperature, humidity and photoperiod.

Table 30 Effect of Temperature and Relative Humidity manipulation on incubation and hatchability of muga silkworm *Antheraea assama* Ww. during April-May

	Incubation Period					Hatching Duration					Hatching %				
	R_1	**R_2**	**R_3**	**R_4**	**Mean**	**R_1**	**R_2**	**R_3**	**R_4**	**Mean**	**R_1**	**R_2**	**R_3**	**R_4**	**Mean**
T_1	21	21	20	20	**20.50**	7	7	7	7	**7.00**	52.00	50.00	46.82	40.00	**47.21**
T_2	10	10	9	9	**9.50**	7	7	7	7	**7.00**	54.52	54.67	53.14	42.00	**51.08**
T_3	8	8	8	8	**8.00**	5	5	5	5	**5.00**	63.33	73.33	65.00	57.00	**64.67**
T_4	8	8	8	8	**8.00**	5	5	5	5	**5.00**	47.00	49.50	33.11	26.00	**38.90**
T_5	7	7	7	7	**7.00**	4	4	4	4	**4.00**	22.00	20.07	14.12	8.00	**16.05**
Mean	**10.80**	**10.80**	**10.40**	**10.40**	**10.60**	**5.60**	**5.60**	**5.60**	**5.60**	**5.60**	**47.77**	**49.51**	**42.44**	**34.60**	**43.58**
S Em (±)	0.30					0.26					0.69				
CD (P= 0.05)	**0.86**					**0.74**					**1.96**				
Control : 26.65 ^{0} C, 68 % RH	8					5					44.79				

Where, $T_1 = 15\ ^0$ C, $T_2 = 20\ ^0$ C, $T_3 = 25\ ^0$ C, $T_4 = 30\ ^0$ C and $T_5 = 35\ ^0$ C
R_1 = 65% RH, R_2 = 75% RH, R_3 = 85% RH and R_4 = > 90% RH

Table 31 Effect of Temperature and Relative Humidity manipulation on incubation and hatchability of muga silkworm *Antheraea assama* Ww. during August-September

	Incubation Period					Hatching Duration					Hatching %				
	R_1	**R_2**	**R_3**	**R_4**	**Mean**	**R_1**	**R_2**	**R_3**	**R_4**	**Mean**	**R_1**	**R_2**	**R_3**	**R_4**	**Mean**
T_1	22	22	22	21	**21.75**	7	7	7	7	**7.00**	60.00	61.87	51.09	45.00	**54.49**
T_2	10	10	9	9	**9.75**	7	7	7	7	**7.00**	70.08	72.00	68.00	46.00	**64.02**
T_3	9	8	8	8	**8.50**	5	5	5	5	**5.00**	75.00	85.00	79.93	50.00	**72.48**
T_4	8	8	8	8	**8.00**	5	5	5	5	**5.00**	64.88	68.00	52.00	48.00	**58.22**
T_5	8	9	7	7	**7.50**	5	5	4	4	**4.50**	53.16	52.00	45.15	35.22	**46.38**
Mean	**11.40**	**11.20**	**11.00**	**10.80**	**11.10**	**5.80**	**5.80**	**5.60**	**5.60**	**5.70**	**64.62**	**67.77**	**59.23**	**44.84**	**59.12**
S Em (±)	0.23					0.18					0.32				
CD (P= 0.05)	**0.65**					**0.51**					**0.91**				
Control : 28.92 ^{0} C, 77.5 % RH	7					5					63.03				

Where, $T_1 = 15\ ^0$ C, $T_2 = 20\ ^0$ C, $T_3 = 25\ ^0$ C, $T_4 = 30\ ^0$ C and $T_5 = 35\ ^0$ C
R_1 = 65% RH, R_2 = 75% RH, R_3 = 85% RH and R_4 = > 90% RH

Table 33 Effect of Temperature, Relative Humidity and Photoperiod manipulation on hatchability of muga silkworm *Antheraea assama* Ww. during August – September

Temperature & RH / Photoperiod (L)	20 ^{0}C+75%	25 ^{0}C+65%	25 ^{0}C+75%	25 ^{0}C+85%
6L	61.58	63.57	75.23	78.43
9L	70.52	72.51	79.21	80.00
12L	73.50	81.20	89.68	85.82
15L	75.49	83.40	90.91	88.02
18L	76.48	83.83	92.97	91.54
Mean	**71.52**	**76.90**	**85.60**	**84.67**
S Em (±)	0.04	0.06	0.05	0.48
CD (P = 0.05)	**0.13**	**0.19**	**0.18**	**1.58**

Control : 28.92 ^{0} C (Temp.)
77.5 % (RH)
12.40 L (Day length)

During April-May, hatching percentage was improved from 44.79% to 73.33% when the temperature and relative humidity were manipulated as 25^{0}C and 75% RH and it was further improved from 73.33% to 81.07% when the photoperiod was also manipulated along with the temperature and humidity (25^{0}C and 75% RH) at 18 L condition.

During August-September, hatching percentage was also improved from 63.03% to 85% when the temperature and relative humidity were manipulated as 25°C and 75% RH and it was further improved from 85% to 93% when the photoperiod was also manipulated along with the temperature and humidity (25^{0}C and 75% RH) at 18 L condition.

So, during both the seed crop rearing seasons, manipulation of abiotic factors as 25^{0}C temperature along with 75% relative humidity and 18 L photoperiod improved the hatching percentage to a greater extent.

4.3. Synchronization of male and female moth emergence and mating behaviour studies for quantitative improvement of quality seed production :

4.3.1. Synchronization in normal condition :

Male and female moths emerged up to four days were utilized in all possible combinations (T_1 to T_{16}) during March – April (cocoon collected from February – March rearing) and September – October (cocoon collected from August – September rearing) to record coupling efficacy, fecundity and hatching percentage.

4.3.1.1. Coupling efficacy :

4.3.1.1.1. During March-April :

Highly significant variation (23.33% to 96.33%) was observed in all the treatments. Highest coupling efficacy was observed in T_1 (96.33%) followed significantly by T_5 (95%), T_9 (93.33%) and others. Significant decrease in coupling efficacy was observed from T_1 to T_4, T_5 to T_8, T_9 to T_{12} and T_{13} to T_{16}.

4.3.1.1.2. During September - October :

Significant variation ranging from 6% to 71.83% coupling efficacy was observed. Highest coupling efficacy was observed in T_1 (71.83%) followed non-significantly by T_5 (70.67%) and significantly by T_9 (68.33%) and others. Significant decrease in coupling efficacy was observed from T_1 to T_4, T_5 to T_8, T_9 to T_{12} and T_{13} to T_{16}. Poor coupling efficacy was observed from T_{16} (6%) T_{12} (10%) and T_{15} (15.83%).

Irrespective of treatments coupling efficacy during March – April (71.27 %) was observed significantly better than September - October. However, coupling efficacy of 1st day male and female, 2nd day male and 1st female and 3rd day male and 1st female were higher in both periods. Females of 2nd or 3rd or 4th day performed in a decreasing trend. It was further recorded that 4th day male when allowed to mated with 1st day female showed 85% of coupling efficacy in March – April. This phenomenon shows that female moth is the more determining factor than male regarding coupling efficacy. With the increased age of male though decreased the coupling efficacy but the increased age of female decreased the coupling efficacy more prominently (figure 6 & 7).

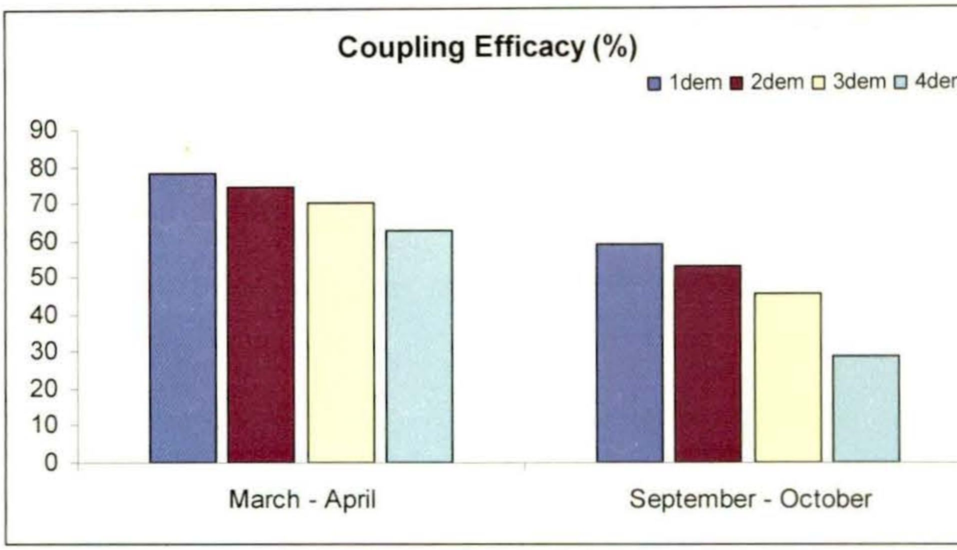

Figure 6 Effect of male influence on coupling efficacy at normal condition

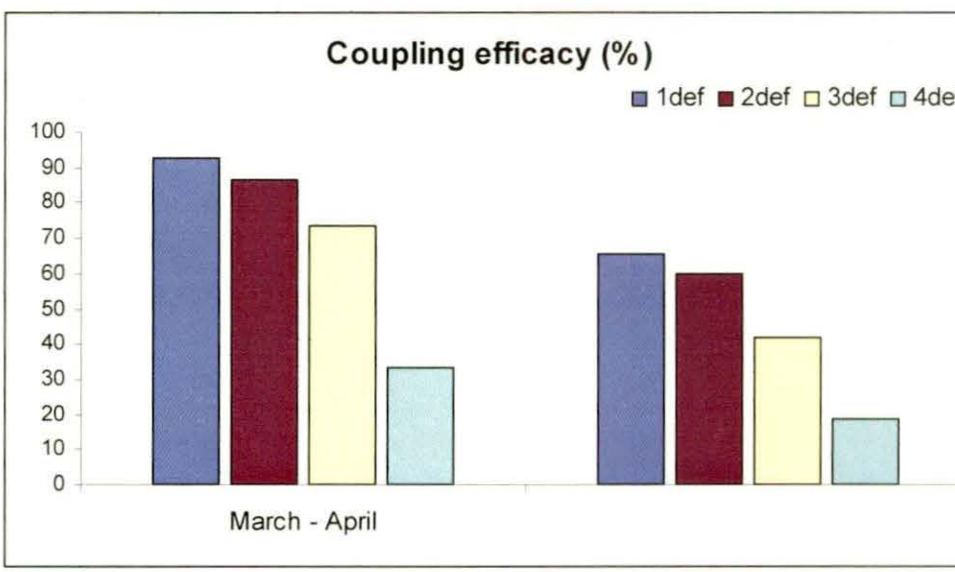

Figure 7 Effect of female influence on coupling efficacy at normal condition

4.3.1.2. Fecundity :

4.3.1.2.1. During March-April :

Significant variation was observed (110.33 to 242.67). Highest fecundity was observed in T_1 (242.67) followed by T_2 (240.67), T_5 (222.67) and others. Significant decrease in fecundity was observed from T_1 to T_4, T_5 to T_8, T_9 to T_{12} and T_{13} to T_{16}. Lowest fecundity was observed by T_{16} (110.33) followed by T_{15} (117.33).

Table 34 Synchronization of moth emergence of muga silkworm, *Antheraea assama* Ww. in normal condition

Treatments (♂ x ♀)	Coupling Efficacy (%)		Fecundity (no.)		Hatchability (%)	
	March - April	September - October	March - April	September – October	March - April	Sept.- Oct.
T_1 (1st dem x 1st def)	96.33	71.83	242.67	179.67	95.06	63.09
T_2 (1st dem x 2nd def)	92.00	69.33	240.67	176.33	92.52	60.68
T_3 (1st dem x 3rd def)	80.33	60.67	217.67	162.00	89.74	59.26
T_4 (1st dem x 4th def)	43.33	33.33	160.33	122.67	85.06	57.34
T_5 (2nd dem x 1st def)	95.00	70.67	222.67	168.67	94.61	61.26
T_6 (2nd dem x 2nd def)	89.67	66.00	215.67	159.67	93.05	58.25
T_7 (2nd dem x 3rd def)	78.33	50.00	202.00	151.67	84.98	55.16
T_8 (2nd dem x 4th def)	35.00	25.00	146.33	112.33	79.74	49.89
T_9 (3rd dem x 1st def)	93.33	68.33	209.67	115.67	84.10	54.77
T_{10} (3rd dem x 2nd def)	83.67	63.33	190.33	141.00	79.69	50.36
T_{11} (3rd dem x 3rd def)	71.67	40.00	189.00	120.33	74.18	44.88
T_{12} (3rd dem x 4th def)	30.67	10.00	130.33	90.67	49.61	31.99
T_{13} (4th dem x 1st def)	85.00	51.67	150.67	111.00	69.70	38.42
T_{14} (4th dem x 2nd def)	79.33	40.33	140.00	93.67	63.34	35.56
T_{15} (4th dem x 3rd def)	63.33	15.83	117.33	83.33	44.87	20.46
T_{16} (4th dem x 4th def)	23.33	6.00	110.33	72.33	29.88	15.65
Mean	**71.27**	**46.40**	**180.35**	**128.81**	**75.63**	**47.31**
S Em (±)	**1.31**	**1.47**	**1.84**	**0.91**	**0.94**	**1.07**
CD (P = 0.05)	**3.78**	**4.26**	**5.30**	**2.64**	**2.72**	**3.10**

dem = Day Emerged Male, **def** = Day Emerged Female

4.3.1.2.2. During September - October :

Significant variation was also observed among the treatments ranging from 72.33 to 179.67. Highest fecundity was observed in T_1 (179.67) followed by T_2 (176.33), T_5 (168.67) and others. Significant decrease in fecundity was observed from T_1 to T_4, T_5 to T_8, T_9 to T_{12} and T_{13} to T_{16}. Lowest fecundity was observed in T_{16} (72.33.%) followed by T_{15} (83.33%).

Among the seasons, fecundity observed significantly higher during March-April (180.35) than September - October (128.81) irrespective of treatments. The fecundity was higher in 1st day male coupled with 1st day female, 1st day male coupled with 2nd day female and 2nd day male coupled with 1st day female in both the seasons. Moreover, males and females beyond 2nd day when coupled in any combination showed abrupt decrease of fecundity and performance of 4th day male and 2nd to 4th day female were very poor in both the seasons. The age of both male and female influenced the fecundity during old age (3^{rd} or 4^{th} day) (figure 8 & 9).

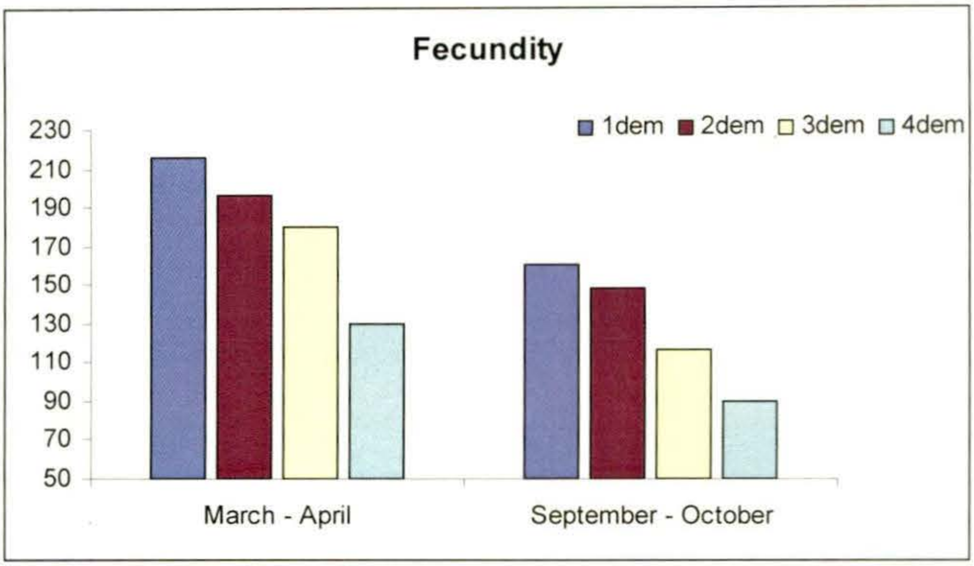

Figure 8 Effect of male influence on fecundity at normal condition

4.3.1.3. Hatching percentage :

4.3.1.3.1. During March April :

Significantly highest hatching number was observed in T_1 (95.06%) followed by T_5 (94.61%) and T_6 (93.05%), however no significant variation was observed between T_5 and T_6. A significant decrease in hatching percentage was observed from T_1 to T_4, T_5 to T_8, T_9 to T_{12} and T_{13} to T_{16}. Lowest hatching percentage was observed in T_{16} (29.88%) followed by T_{15} (44.87%).

4.3.1.3. 2. During September - October :

Significantly highest hatching number was recorded in T_1 (63.09%) followed by T_5 (61.26%) and T_2 (60.68%), however no significant variation was observed between T_5 and T_2. Significant decrease in hatching percentage was observed from T_1 to T_4, T_5 to T_8, T_9 to T_{12} and T_{13} to T_{16}. Lowest hatching percentage was observed in T_{16} (15.65%) followed by T_{15} (20.46%).

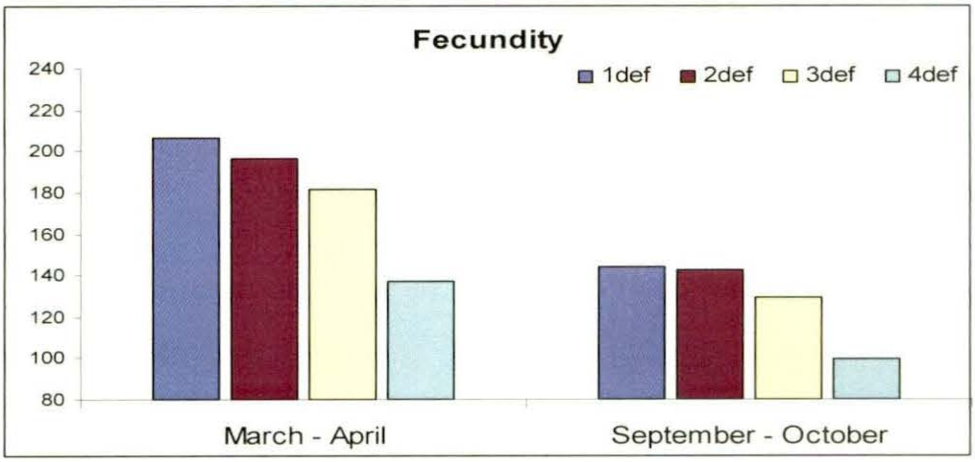

Figure 9 Effect of female influence on fecundity at normal condition

Hatching percentage during March-April (75.63) observed better than hatching percentage during September - October (47.31). During March – April up to 2^{nd} day male and female in all possible combinations and 3^{rd} day male and up to 2^{nd} day female in combination performed better while during September - October moth beyond 2^{nd} day the performances were poor. Showing that older the age of male and female moth lesser the hatching percentage (Figure 10 & 11).

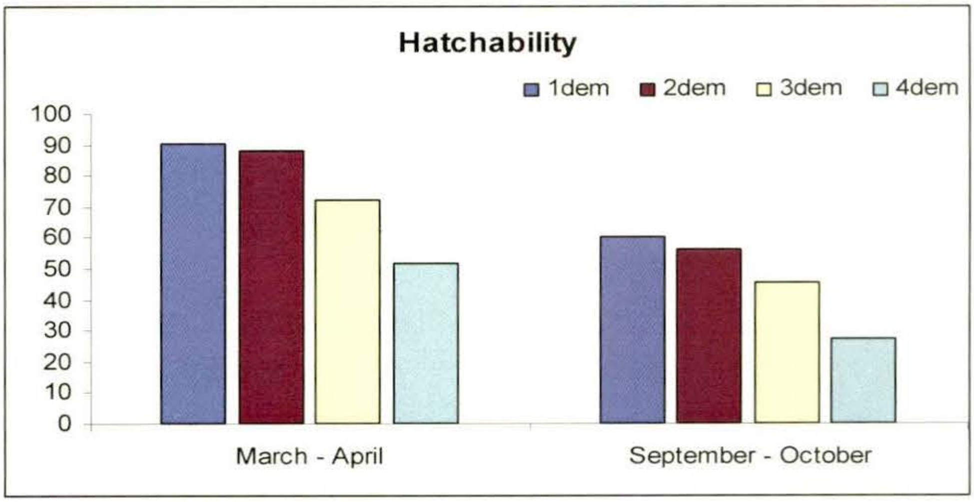

Fig 10 Effect of male influence on hatchability at normal condition

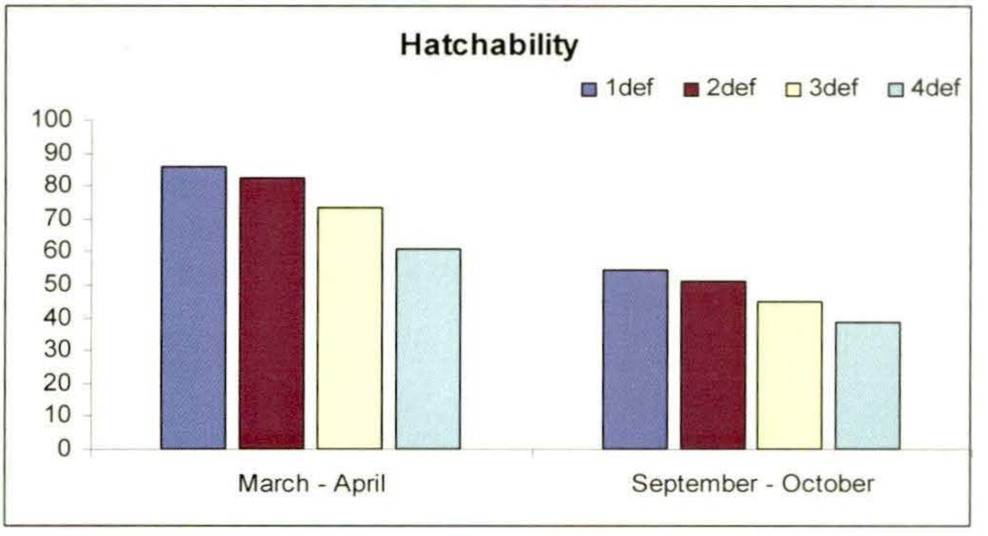

Figure 11 Effect of female influence on hatchability at normal condition

Overall results reflected that March-April was much better season than September - October regarding synchronization of male and female emergence for all the possible combinations up to 4^{th} day.

Among the treatments, freshly emerged adults (both male and female) performed best for all the parameters studied (T_1). However, first day male mated with second day female (T_2), second day male mated with first (T_5) and second (T_6) day female when utilized for grainage operation performed better. However a decreasing trend was observed from first day female to fourth day female using the male of any day upto fourth day.

Keeping under consideration that the grainage performance during September - October was to some extent poor than during March-April utilization 4^{th} day male for all the 4 days females (T_{13} to T_{16}) was very poor. Still the performance of fourth day male with first and second day female (T_{13} to T_{14}) were better among the four treatments.

4.3.2. Short term cold preservation of moth for synchronized mating :

Male and females moths emerged up to 3 days were preserved and coupled in all possible combinations (15) with a control batch of fresh male and female to record the coupling efficacy, fecundity and hatchability during March – April and September - October.

4.3.2.1. Coupling efficacy :

4.3.2.1.1. During March-April :

The coupling efficacy during this period ranged from 83.36% to 96.67%. Fresh male and fresh female (T_1) when coupling with each other the efficacy observed 96.33%. T_5 (96.67%), T_8 (96.62%) and T_{11} (96.60%) having non-significant variation performed significantly better than T_1. Better performance was also observed from T_9 (93.45%), T_2 (93.40%) and T_{14} (93.38%) having non-significant variation between them. However, significantly lowest coupling efficacy was observed from T_{16} (73.36%) and all other treatments showed more than 85% coupling efficacy.

4.3.2.1.2. During September - October :

The coupling efficacy during the period ranged from 56% to 73.08%. T_5 (73.08%), T_8 (72.92%) and T_{11} (72.58%) having non-significant variation showed significantly better coupling efficacy than fresh male and female coupling (T_1 : 71.83%) and others. The performance of T_2 (70.08%), T_9 (69.10%) and T_6 (69.09%) were also good having non-significant differences between them. Significantly lowest coupling efficacy was observed in T_{16} (56%) and all other treatments showed above 60% coupling efficacy.

Coupling efficacy was observed better during March – April (91.32 %) than September - October (66.94 %). One day preserved female when allowed to coupled with fresh or one/two day(s) preserve male significantly improved the coupling efficacy over control (fresh male and female). Fresh female when allowed to coupled with one day preserved male or fresh male when allowed to coupled with two days preserved female and even one day preserved male coupling with two days preserved female or three days preserved male coupling with one day preserved female also improved the coupling efficacy which were above 93% and 68% during March – April and September - October respectively. So, female moth under one day preservation performed better and it was further observed that preservation length affected coupling efficacy more prominently in female than in male (figure 12 & 13).

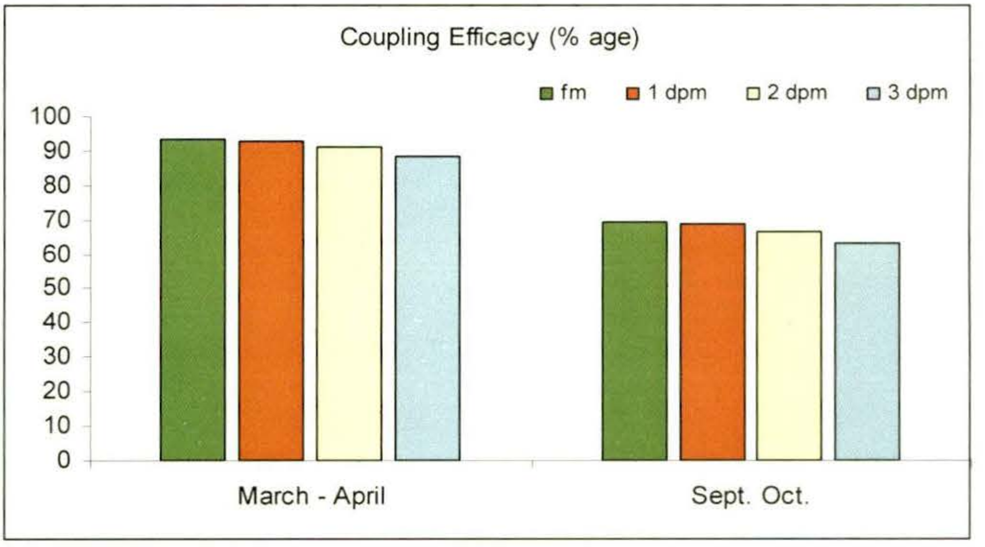

Figure 12 Effect of male influence on Coupling Efficacy by preservation

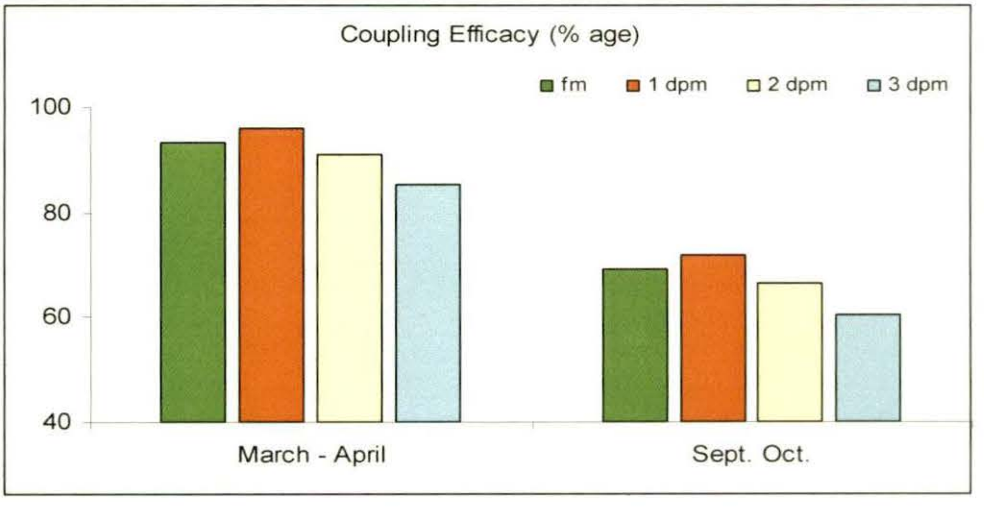

Figure 13 Effect of female influence on coupling efficacy at normal condition

4.3.2.2. Fecundity :

4.3.2.2.1. During March-April :

Fecundity during the period ranged from 227.33 to 248.00 in the treatments. T_5 (248.00) showed significantly highest fecundity followed by T_8 (246.67) and others. T_1 (243.00), T_2 (242.67), T_3 (242.33) and T_{11} (243.00) showed better fecundity having non-significant variation between them. Except T_{16} where the fecundity recorded 227.33 and T_{13} where fecundity recorded 230.00 all other treatments showed fecundity above 230.00.

Table 35 Effect of coupling of fresh and different day preserved adults at 10±1^0 C on fecundity and hatchability of muga silkworm, *Antheraea assama* Ww.

Treatments (♂ x ♀)	Coupling Efficacy (%)		Fecundity (no.)		Hatchability (%)	
	March - April	September - October	March - April	September - October	March - April	September - October
T_1 (fm x ff))	96.33	71.83	243.00	179.67	95.63	63.33
T_2 (1dpm x ff)	93.40	70.08	242.67	180.00	95.92	63.50
T_3 (2dpm x ff)	93.15	68.75	242.33	180.00	94.99	62.45
T_4 (3dpm x ff)	90.13	65.51	241.33	178.33	95.00	62.28
T_5 (Fm x 1 dpf)	96.67	73.08	248.00	185.33	95.98	65.02
T_6 (Fm x 2 dpf)	93.17	69.09	239.33	177.33	95.42	62.97
T_7 (Fm x 3 dpf)	86.58	63.04	233.67	170.00	94.33	61.50
T_8 (1dpm x 1 dpf)	96.62	72.92	246.67	182.00	95.78	64.62
T_9 (1dpm x 2 dpf)	93.45	69.10	238.33	173.00	95.33	62.33
T_{10} (1dpm x 3 dpf)	86.46	61.96	232.00	169.33	93.33	59.33
T_{11} (2dpm x 1 dpf)	96.60	72.58	243.00	178.67	95.23	65.33
T_{12} (2 dpm x 2 dpf)	90.18	65.05	235.33	171.00	95.12	63.12
T_{13} (2 dpm x 3 dpf)	85.36	60.23	230.00	167.33	94.00	60.33
T_{14} (3 dpm x 1 dpf)	93.38	68.83	236.33	173.33	95.33	61.33
T_{15} (3 dpm x 2 dpf)	86.68	62.95	230.67	172.33	95.18	60.42
T_{16} (3 dpm x 3 dpf)	83.36	56.00	227.33	164.33	92.11	58.33
Mean	**91.32**	**66.94**	**238.12**	**175.12**	**94.92**	**62.26**
S Em (±)	**0.06**	**0.26**	**0.34**	**0. 40**	**0.32**	**0.28**
CD (P = 0.05)	**0.17**	**0.74**	**1.00**	**1.14**	**0.92**	**0.80**

dpm = Day Preserved Male, **dpf** = Day Preserved Female,
fm = Fresh Male, **ff** = Fresh Female

4.3.2.2.2. During September - October :

Fecundity ranged between 164.33 and 185.33. Fecundity recorded highest in T_5 (185.33) followed significantly by T_8 (182.00) and others. T_1 (179.67) having non-significant difference with T_2 (180.00), T_3 (180.00) and T_{11} (178.67) showed better performance. T_{16} (164.33) performed worst followed by T_{13} (167.33) and T_{10} (169.33). Rest of the treatments showed fecundity more than 170.00.

Fecundity was observed better during March – April (238.12) than September - October (175.12). One day preserved female showed better fecundity and even better than freshly utilized

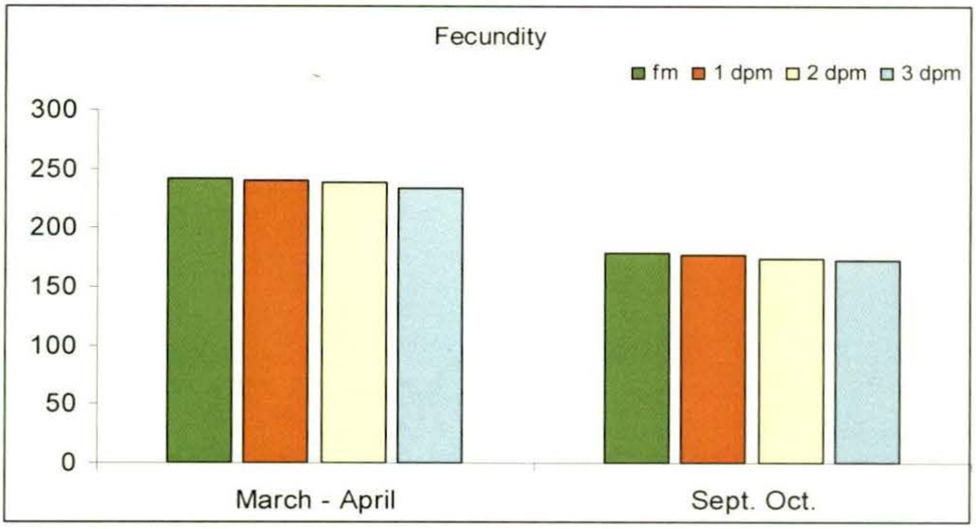

Figure 14 Effect of male influence on fecundity by preservation

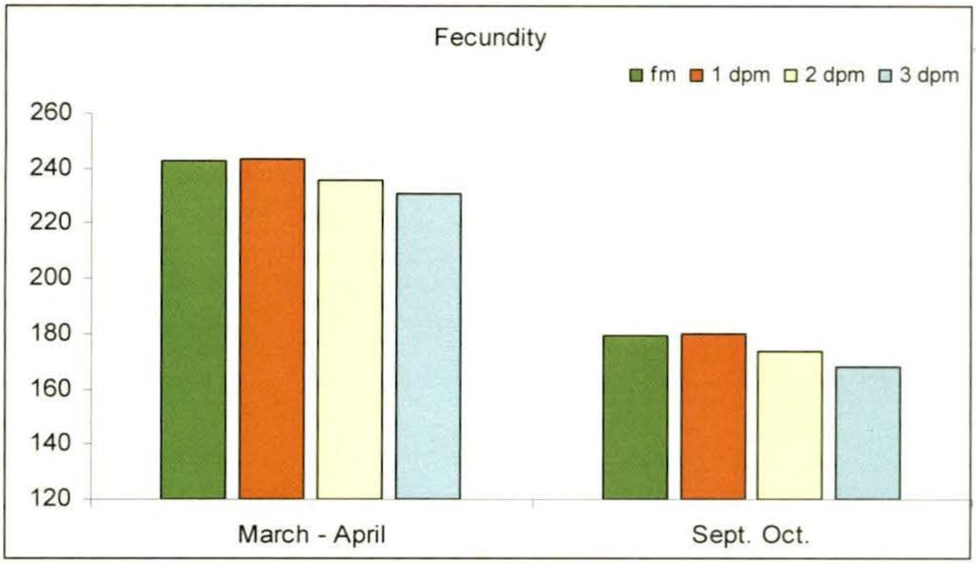

Figure 15 Effect of female influence on fecundity at normal condition

male and female when mated with fresh male and one day preserved male. Female showed more prominent effect than male under preservation (Figure 14 & 15).

4.3.2.3. Hatchability :

4.3.2.3.1. During March-April :

Hatching percentage during this period ranged between 95.63 to 92.11 having significant difference. T_1, T_2, T_3, T_4, T_5, T_6, T_8, T_9, T_{11}, T_{12}, T_{14} and T_{15} showed no significant difference ranking top in position (95.63 to 94.98 %) followed by others and lowest hatching percentage was obtained from T_{16} (92.11 %) followed significantly by T_{10} (90.33 %).

4.3.2.3.2. During September - October :

Hatching percentage during this period ranged between 65.33 to 58.33 having significant variation. The highest hatchability was recorded in T_{11} (65.33 %) followed non-significantly by T_5 (65.02 %) and T_8 (64.62 %). T_1 (63.33 %) having non-significant variation with T_2 (63.50 %), T_6 (62.97 %) and T_{11} (63.12 %) showed higher hatchability. Significantly lowest hatchability was recorded from T_{16} (58.33 %) followed by T_{10} (59.33 %).

Hatchability during March – April (94.92 %) recorded better than that of during September - October (62.26 %). During March – April, the effect of preservation was not so distinctive as in September - October where preservation of female for one day improved the hatchability over freshly mated female (figure 16 & 17).

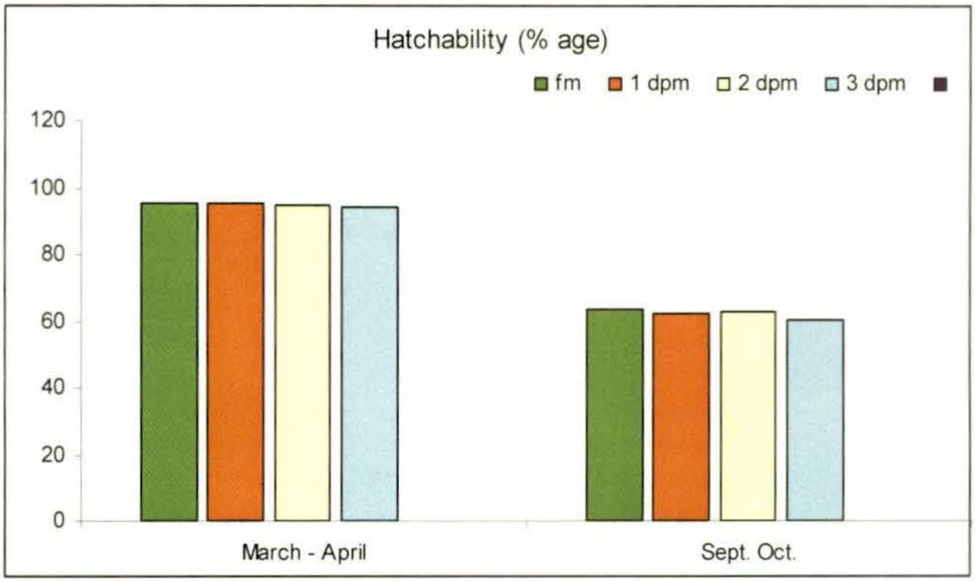

Figure 16 Effect of male influence on hatchability (%) by preservation

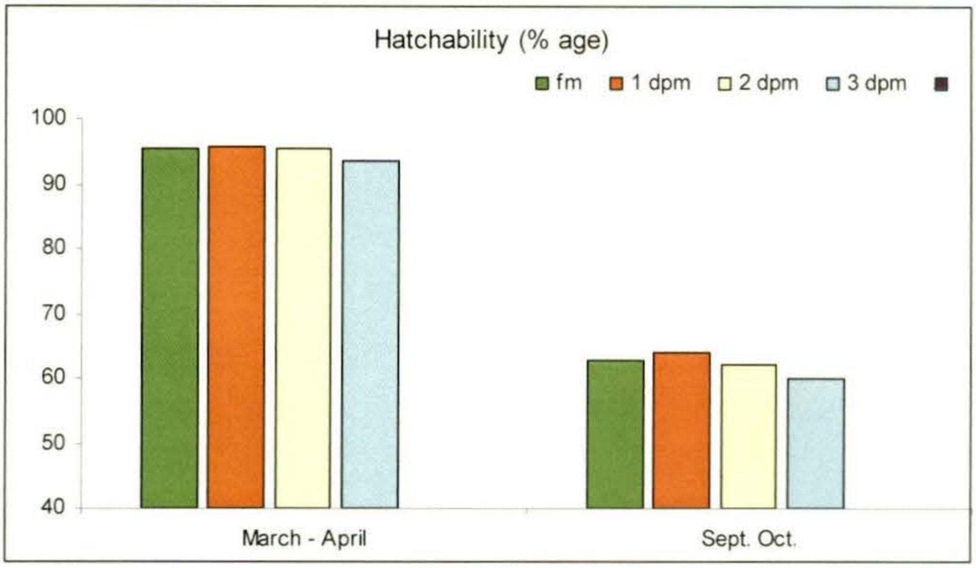

Figure 17 Effect of female influence on hatchability at normal condition

4.3.3. Repeated Mating :

4.3.3.1. Effect of different mating hours on egg laying and hatching :

No significant differences were observed between different mating hours on egg laying, retention, hatching and hatchability. However, highest fecundity was observed when mating was

Table 36 Data on egg laying and hatching as influenced by different mating hours of muga silkworm, *Antheraea assama* Ww.

Mating Hours	Egg laying (no.)	Egg retention (no.)	Hatching (no.)	Hatching Percentage (%)
2 hrs.	267.33	10.00	253.33	94.76
3 hrs.	268.67	8.67	265.33	98.75
4 hrs.	272.67	9.00	265.66	97.42
5 hrs.	279.67	6.33	276.67	98.92
6 hrs.	279.00	6.33	273.33	97.96
7 hrs.	287.00	2.00	284.67	99.18
8 hrs.	275.67	7.67	267.00	96.85
9 hrs.	273.00	5.33	265.67	97.31
10 hrs.	251.67	4.33	249.67	99.10
11 hrs.	251.33	3.33	246.67	98.14
12 hrs.	250.00	6.33	235.00	94.00
CD at 5%	**Non-Significant**	**Non-Significant**	**Non-Significant**	**Non-Significant**

allowed for seven hours (287.00 %), lowest being from 12 hours (250.00 %). Egg retention was 2 to 10. Number of egg hatched was highest from seven hours (284.67 %)

which was 99.19 %, lowest being from 12 hours which was 235.00 and 94% for egg laying and hatchability respectively (Table 36).

4.3.3.2 Effect number of mating utilizing single male moth on egg laying and hatching :

Results obtained from repeated mating during March-April were depicted in table 35 and that of during September-October in table 36.

4.3.3.2.1. During March - April :

During March-April, prior to second commercial crop rearing period i.e. April-May one male moth could be forced to couple with fresh female upto four times.

4.3.3.2.1.1. Egg laying :

Significant variations observed between the treatments. Highest egg laying was recorded when fresh male and female moth were coupled (232 %). A decreasing trend was observed from second time utilization to 4th time utilization of the same male moth. There observed significant variation in egg laying between second (207 %) and third time (194 %) exploitation of the same male moth. But significantly abrupt decreased egg laying was observed when extreme utilization of male moth for the fourth time was done (75 %).

Table 37 Data on grainage performance as influenced by repeated mating of muga silkworm *Antheraea assama* Ww. during March-April.

Treatments	Egg laying (no.)	Egg Retention (no.)	Hatching (no.)
Fresh male x Fresh Female	232.00	7.00	231.00
Single mated male x Fresh Female	207.00	7.33	197.00
Double mated male x Fresh Female	194.00	15.00	164.00
Triple mated male x Fresh Female	75.00	140.00	0.00
C.D. at 5%	**2.769**	**9.400**	**4.123**

4.3.3.2.1.2. Egg Retention :

Egg retention was not significantly higher inside the female bodies upto 3rd time utilization of a single male (7 to 15 %). But the egg retention in the female body when coupled with a male utilizing for the 4th time was very high (140.00 %) which was even nearly double than the egg laid by that female.

4.3.3.2.1.3. Hatching :

Hatching no. was significantly highest (231.00 %) from the egg laid by the female coupled with fresh male. The hatching number recorded 197.00 and 164.00 from the egg laid by the females repeatedly utilization of males for 2nd and 3rd times respectively. Most striking observation was that no egg was hatched when the female mated with the male utilizing for the fourth time.

4.3.3.2.2. During September - October :

During September - October prior to main commercial rearing i.e. October-November one male moth could be exploited upto 6th times to mate the fresh females.

Table 38 Data on grainage performance as influenced by repeated mating during September-October of muga silkworm (*Antheraea assama* Ww.).

Treatments	Egg laying (no.)	Egg Retention (no.)	Hatching (no.)
Fresh male x Fresh Female	264.33	6.00	262.00
Single mated male x Fresh Female	252.00	11.67	247.33
Double mated male x Fresh Female	254.33	6.66	248.67
Triple mated male x Fresh Female	248.00	15.67	244.00
Tetra mated male x Fresh Female	237.00	25.00	198.
Penta mated male x Fresh Female	135.67	125.00	0.00
C.D. at 5%	**7.08**	**5.42**	**5.52**

4.3.3.2.2.1. Egg laying :

Like March-April, during September - October also the egg laying was found significantly highest (264.33 %) when fresh female were coupled with fresh male. Egg laid by the females mated with the males utilizing for 2nd, 3rd and 4th times had non-significant variation among them (248.00 – 254.33 %). Egg laid by the females mated with the male exploited for the 5th time was significantly lower (237.33 %). But repeated utilization of the male moth for the 6th time reflected very low egg laying by the female coupled with (135.67 %).

4.3.3.2.2.2. Egg retention :

Egg retention was 6 to 16 inside the female bodies coupled with upto 4^{th} time utilization of single male moth. Very huge amount of egg retention (125.00 %) was recorded inside the female body when mated with a male utilized earlier for the five times.

4.3.3.2.2.3. Egg hatching :

Significantly highest hatching no. was observed by the eggs laid by the female when coupled with fresh male (262.00 %) followed significantly by the eggs laid by the female mated with the males for 2^{nd} to 4^{th} times (244.00 – 248.67 %). Hatching number decreased significantly in the eggs laid by the females mated by the male repeatedly used for the 5^{th} time (198.67 %). Surprisingly no eggs was hatched the females when coupled with the male utilized for sixth time.

Results from repeated mating showed that during March – April repeated mating could be done upto three times and during September - October it could be upto four times.

4.4. Characterization of seed Cocoon

4.4.1. Preliminary Screening of seed cocoon :

Preliminary screening of seed cocoon was done on the basis of cocoon weight, cocoon length and cocoon width and their individual as well as combined reflections on fecundity, hatchability and egg vigour were measured. The primary screening was on female cocoon only. Female cocoons were grouped under four groups as light, (weight : 4.50-5.50 g length : 3.50cm-4.00 cm and width : 5.52-5.90cm) average, (weight: 5.50-6.50 g length :4.00-4.50cm, width : 5.90-6.30cm),moderate, (weight: 6.50-7.50 g length : 4.50-5.00 width : 6.30-6.70cm) and heavy (weight : 7.50-8.50g length : 5.00-5.50cm width : 6.70-7.10cm).

4.4.1.1. Screening on the basis of cocoon weight :

The observation was made considering the weight only.T_3 and T_4 reflected highest realised fecundity (238 & 241respectively), laying upto three days (202 for both), egg weight (1.52g & 1.54g respectively) and hatching number (204 &210 respectively) having non-significant variation among them and followed significantly by others. Lowest performance was observed from T_1 (190,164,159 and 1.19g for realised fecundity, fecundity up to 3 days, hatching number and egg weight respectively) significantly followed by T_2 (222,186,188 and 1.40g for realised fecundity, fecundity up to 3 days, hatching number and egg weight respectively). (Table 39).

Table 39 Preliminary screening on the basis of cocoon weight

Treatment	Fecundity		Hatchability	Egg vigour
	Realized	Up to 3rd Day	(In number)	In weight (g) / laying
T_1	190.00	164.00	159	1.19
T_2	222.00	186.00	188	1.40
T_3	238.00	202.00	204	1.52
T_4	241.00	202.00	210	1.54
Mean	222.75	188.50	190.25	1.41
S Em (±)	3.17	3.32.	2.66	0.04
CD (P = 0.05)	10.99	11.50	9.22	0.12

T_1 : Light, T_2 : Average, T_3 : Moderate, T_4 : Heavy

4.4.1.2. Screening on the basis of cocoon length:

The observation was made considering the length only. Significant variation was observed among the treatments on different grainage parameters. Realised fecundity, laying upto three days, egg vigour and hatching number were observed significantly highest T_4 (242, 215, 1.47g and 204 respectively) followed by T_3 (228,188, 1.39g and 193) and lowest in T_1 (176, 140, 1.08g and 150 respectively). (Table 40).

Table 40 Preliminary screening on the basis of cocoon length

Treatment	Fecundity		Hatchability	Egg vigour
	Realized	Up to 3rd Day	(In number)	In weight (g) / laying
T_1	176.00	140.00	150	1.08
T_2	210.00	176.00	178	1.28
T_3	228.00	188.00	193	1.39
T_4	242.00	215.00	204	1.47
Mean	214.00	179.75	181.25	1.30
S Em (±)	2.85	1.55	0.75	0.02
CD (P = 0.05)	**9.86**	**5.38**	**2.58**	**0.06**

T_1 : Light, T_2 : Average, T_3 : Moderate, T_4 : Heavy

4.4.1.3 Screening on the basis of cocoon width:

The observation was made considering the width only. Significantly highest realized fecundity, laying upto three days, egg vigour and hatching number were observed in T_4 (255, 222, 1.53g and 208 respectively).No significant variation was observed between T_2 and T_3 and lowest from T_1(198,161,1.27g,171repectively). (Table 41)

Table 41 Preliminary screening on the basis of cocoon width

Treatment	Fecundity		Hatchability	Egg vigour
	Realized	Up to 3rd Day	(In number)	In weight (g) / laying
T_1	198.00	161.00	171	1.27
T_2	231.00	191.00	198	1.45
T_3	234.00	198.00	204	1.49
T_4	255.00	222.00	208	1.53
Mean	229.50	193.00	195.25	1.43
S Em (±)	2.52	3.01	0.99	0.01
CD (P = 0.05)	**8.73**	**10.43**	**1.44**	**0.04**

T_1 : Light, T_2 : Average, T_3 : Moderate, T_4 : Heavy

4.4.1.4. Screening on the basis of cocoon weight, length and width:

Four (4) treatments were taken under consideration namely, Light where cocoon weight ranged from 4.50 g to 5.50 g, length ranged from 3.50 cm - 4.00 cm and width ranged from 5.52 to 5.90 cm. Average where cocoon weight, length and width were 5.50 g -6.50 g, 4.00 cm - 4.50 cm. and 5.90 cm-6.30 cm respectively ; Moderate ranged from 6.50 g- 7.50 g, 4.50 cm- 5.00 cm and 6.30-6.70 cm for weight, length and width respectively and Heavy where cocoon weight was 7.50-8.50 g, length was 5.00 - 5.50 cm and width was 6.70 cm. to 7.10 cm respectively. Fecundity, egg vigour and hatchability were recorded and analysis statistically. (Table 42).

Table 42 Preliminary screening on the basis of cocoon weight, cocoon length and cocoon width.

Treatment	Measurement of female cocoon			Fecundity		Hatchability	Egg vigour
	Weight	Length	Width	Realized	Up to 3^{rd} Day	In number	In weight (g) / laying
T_1	5.04	3.78	5.65	188.00	155.00	160.00	1.152
T_2	6.05	4.25	6.13	221.85	184.00	188.60	1.381
T_3	7.10	4.70	6.56	233.19	196.00	200.60	1.471
T_4	7.92	5.25	6.87	246.22	213.00	207.20	1.500
Mean	**6.53**	**4.50**	**6.30**	**222.32**	**187.00**	**189.10**	**1.38**
S Em (±)	0.09	0.19	0.17	3.70	3.08	3.90	0.03
CD (P = 0.05)	**0.27**	**0.60**	**0.51**	**11.40**	**10.65**	**12.03**	**0.09**

T_1 : Light, T_2 : Average, T_3 : Moderate, T_4 : Heavy

Fecundity :

Realised : Realised fecundity was observed significantly highest (246.22) in T_4 followed significantly by T_3 (233.19) and by others and showed lowest in T_1(188.00).

Up to 3 days laying : upto 3 days laying the observation showed significant variation among the treatments highest being from T_4 in the order of $T_4 > T_3 > T_2 > T_1$.

Egg vigour : No significant variation was observed between T_4 and T_3, T_3 and T_2 . However, highest egg vigour was observed in T_4 (1.5 g) and lowest from T_1(1.15g) having a difference of 0.35 g per laying and the variation was significant.

Hatchability : Hatchability in terms of hatching numbers showed highest hatching from the eggs of T_4 treatment (207.20) followed non-significantly by T_3 (200.60) and significantly by others. However, there observed no significant variation between T_3 and

T_2.There observed 47 number of hatched larval difference between T_1 and T_4 treatments having highly significant variation.

So, it can be said that regarding fecundity (realised and upto three days laying) significant variation was observed following the trend of Heavy > Moderate > Average > Light. In case of egg vigour and hatchability no significant variation was observed between Heavy and Moderate as well as between Moderate and Average, though the difference between Heavy and Average or Light was significant.

4.4.1.5. Co-relation Study :

Table 43 indicates correlation coefficient (r), regression equation and the deviation among the treatments from their own experiment between various cocoon measurement and grainage parameters.

Table 43 Correlation study

Measurements	Mean ± SD	Corr. Coeff. (r)	Regression equation	Estimated value	Deviation from observed value
Real Fecundity					
Weight	6.53 ± 1.25	0.97*	Y = 96.43 + 19.28 x	222.33	+0.01
Length	4.50 ± 0.63	0.96*	Y = 51.65 + 37.96 x	222.47	+0.15
width	6.30 ± 0.53	0.98*	Y = - 67.74+ 46.02 x	222.19	-0.13
3rd Day Fecundity					
Weight	6.53 ± 1.25	0.98*	Y = 61.66 + 19.20 x	187.04	+0.04
Length	4.50 ± 0.63	0.97*	Y = 15.7 + 38.10 x	187.16	+0.16
width	6.30 ± 0.53	0.99**	Y = - 100.31 + 45.59 x	186.91	-0.09
Hatchability in number					
Weight	6.53 ± 1.25	0.96*	Y = 84.67 + 16.00 x	190.25	+0.05
Length	4.50 ± 0.63	0.94	Y = 98.73 + 31.22 x	181.25	50.12
width	6.30 ± 0.53	0.98*	Y = - 52.18 + 38.28 x	195.25	-0.12
Hatching Weight					
Weight	6.53 ± 1.25	0.94	Y = 0.61 + 0.12 x	1.41	+0.01
Length	4.50 ± 0.63	0.92	Y = 0.35 + 0.23 x	1.30	+0.01
width	6.30 ± 0.53	0.96*	Y = - 0.43 + 0.29 x	1.43	+0.01

*** significant at 5 % level of confidence ** significant at 1 % level of confidence**

The 'r' values of all the measurements, namely cocoon weight, cocoon length and cocoon width, were found significant at 5% (p=0.05) level of significance for realized fecundity. The 'r' values of cocoon weight and length showed 5% level of significance and the cocoon width showed 1% level of significance for up to three (3) days fecundity. From the standpoint of hatchability the weight and width showed 5% level of significance and of hatchability, the weight and width showed 5% level of significance.

Based on the regression equations obtained, estimates of number of eggs, egg vigour and hatchability were worked out and deviations from the mean observed values were given. The estimated realised fecundity based on the weight of cocoon was 222.33 which was the nearest estimated value to the observed realized fecundity of 222.32 as shown by least deviation (+0.01) followed by width (-0.13) and length (+0.15). The estimated upto three days fecundity based on the weight of cocoon was 187.04 which was the nearest estimated value to the observed realised fecundity of 187.00 as shown by least deviation (+0.04) followed by width (-0.09) and length (+0.16). The egg vigour showed same deviation (+0.01) among cocoon weight, length and width. However, the estimated hatchability based on the weight of cocoon was 190.25 which was the nearest estimated value to the observed hatchability of 190.10 as shown by least deviation (+0.05 followed by width (-0.12).

So, from the overall results in terms of observation and correlation and regression analysis it can be said that the performance was better in Heavy, followed by Moderate, Average and Light and among the measuring items cocoon weight was the best estimator followed by cocoon width and cocoon length.

4.4.2. Sex-wise distribution pattern of different cocoon weight group:

After preliminary screening based on four groups, cocoons were grouped under seven weight ranges separately for male and female. The groups were extreme low, lower, low, medium, high, higher and extreme high. In case of female cocoons, weight ranges from 4.50 g to 7.99 g with a 0.50 g limit for each group and male cocoons ranging from 2.50 g to 5.99 g were also subdivided with a 0.50 g limit for each group. Distribution pattern of weight range percentage was calculated.

4.4.2.1. Distribution pattern of male cocoon:

The distribution pattern of different weight range in male cocoons (Table 44) was reflective of normal distribution and indicated predominance of low (24.86%) and

Table 44 Sex wise distribution of different cocoon weight groups

Cocoon weight groups	Male		Female	
	Cocoon weight range	Weight range (%)	Cocoon weight range	Weight range (%)
Extreme low	2.50-2.99	5.72	4.50-4.99	2.00
Lower	3.00-3.49	15.14	5.00-5.49	7.14
Low	3.50-3.99	24.86	5.50-5.99	31.74
Medium	4.00-4.45	26.72	6.00-6.49	33.00
High	4.50-4.99	4.58	6.50-6.99	14.86
Higher	5.00-5.49	1.78	7.00-7.49	4.28
Extreme high	5.50-5.99	0.92	7.50-7.99	2.80

medium (26.72%) weight range followed by lower extreme low, high, higher and extreme high which was lowest (0.92%). The confidence interval at 95 percent revealed that the average male pupa ranges maximum between 4.26 g -4.36 g in normally distributed population.

4.4.2.2. Distribution pattern of female cocoon :

The distribution pattern of different weight range in female cocoon (Table 44) was reflective of normal distribution and indicated predominance of medium (33%) and low (31.74%) weight range followed by high, lower, higher, extreme high and extreme low which was lowest (2.00%). The confidence interval at 95% revealed hat the average female pupa ranges maximum 6.29 g o 6.43 g in normally distributed populations.

4.4.3. Relation between pupal weight and cocoon weight :

Corresponding pupal weight for cocoon weight were depicted in Table 45.

4.4.3.1. Male cocoon weight corresponding male pupal weight :

Male cocoon weigh varied from 2.85 ± 0.02 g to 5.53 (±0.04) g in extreme low to extreme high groups with a significant ascending order of increased weight. Corresponding pupal weight also varied from 2.39 ± 0.05 g to 5.12 ± 0.03 g in extreme low to extreme high groups also having a significant ascending trend.

4.4.3.2. Female cocoon weight corresponding female pupal weight :

Female cocoon weight varied from 4.65 ± 0.02 g to 7.59 ± 0.04 g in extreme low to extreme high groups with a significant ascending increasing trend. Corresponding pupal weight also increased in significant ascending trend from 4.39 ± 0.03 g to 6.98 ± 0.03 g in extreme low to extreme high groups.

Table 45 Relationship between male pupal weight and cocoon weight of muga silkworm.

Cocoon weight groups	Male		Female	
	Mean cocoon weight (g)	Corresponding pupal weight	Mean cocoon weight (g)	Corresponding pupal weight
Extreme low	2.85 (± 0.02)	2.39 (± 0.05)	4.65 (± 0.02)	4.39 (± 0.03)
Lower	3.28 (± 0.06)	2.87 (± 0.04)	5.46 (± 0.06)	4.89 (± 0.04)
Low	3.72 (± 0.04)	3.38 (± 0.04)	5.79 (± 0.04)	5.40 (± 0.03)
Medium	4.31 (± 0.05)	3.90 (± 0.05)	6.36 (± 0.07)	5.90 (± 0.08)
High	4.69 (± 0.06)	4.41(± 0.03)	6.68 (± 0.06)	6.21 (± 0.05)
Higher	5.31 (± 0.03)	4.89 (± 0.04)	7.16 (± 0.03)	6.71 (± 0.06)
Extreme high	5.53 (± 0.04)	5.12 (± 0.03)	7.59 (± 0.04)	6.98 (± 0.03)
Mean	**4.23**	**3.85**	**6.23**	**5.77**
S Em. (±)	0.006	0.006	0.004	0.004
CD (P=0.05)	**0.016**	**0.014**	**0.014**	**0.013**

± values are the confidence interval at 95 %

4.4.3.3. Co-relation studies between cocoon weight and corresponding pupal weight

Correlation coefficients worked out on the basis of mean weight indicated highly significant and positive correlation (r=0.99 and r=0.98) between cocoon and pupal weight in both the sexes (Table 46). From the regression equations was possible to predict and estimate the pupal weight from cocoon weight. It indicated that in case of male cocoon an increase of 0.91 g is pupal weight increased the cocoon weight 1.0g with 98% variation, where as in case of female cocoon an increase of 0.98 g in pupal weight increased the cocoon weight by 1.0g with 99% variation.

Table 46 Regression model for predicting pupal weight (Y) from cocoon weight (X) (complete)

Moreover, female cocoon and pupal weight were observed much higher than male cocoon and pupal weight.

Sl. No.	Sex	Correlation co-efficient	Regression Equation
1.	**Male**	r = 0.98	Y = 0.9071 X + 0.1213
2.	**Female**	r = 0.99	Y = 0.9838 X + 0.4523

*Significant at 5% level of confidence

4.4.4. Fecundity, egg vigour and hatchability as influenced by different combinations of male and female cocoon :

Altogether 49 combinations alongwith one control batch were selected based on the groups selected for sex-wise distribution pattern and data thus obtained depicted in Table- 47.

4.4.4.1 On Fecundity :

Highest realised fecundity was observed in F_7 x M_7 (258.33) followed non-significantly by F_7 x M_5 (257.00), F_7 x M_6 (256.33) and F_7 x M_4 (256.00) and significantly by F_6 x M_7 (252.33) and others.

However, no significant variation was observed between F_6 x M_7 (252.33) and F_6 x M_6 (251.00), F_7 x M_2 (251.00) and F_7 x M_3 (251.00), lowest fecundity was observed from F_1 x M_2 (168.33) followed significantly by F_1 x M_1 (173.33).

Fecundity upto three days also showed significant variation. Highest fecundity was observed in F_7 x M_7 (206.67) followed non-significantly by F_7 x M_5 (205.60), F_7 x M_6 (205.07) and F_7 x M_4 (204.80) and significantly by F_6 x M_7 (201.87). However, there observed no significant variation was observed between F_6 x M_7 (201.87) and F_6 x M_6 (200.80), F_7 x M_2 (200.80) and F_7 x M_3 (200.80) and F_6 x M_4 (200.00). Significantly, lowest performance was observed from F_1 x M_5 (135.33).

4.4.4.2 On Hatchability :

Hatching number was significantly varied among treatments. Highest hatching number was recorded in F_7 x M_5 (247.12) and F_7 x M_4 (241.40) and significantly by others. Lowest hatching number was observed in F_1 x M_3 (167.67). Hatching percentage between the treatments varied non-significantly between 96.16% to 93.06 %.

4.4.4.3 On Egg Weight :

Highest egg weight was observed in F_7 x M_5 (1.81g) followed non-significantly by F_7 x M_7 (1.79g) F_7 x M_6 (1.79g), F_7 x M_4 (1.77g) and F_6 x M_7 (1.78g) and followed significantly by others. Lowest egg weight was observed in F_1 x M_2 (1.18g)

Table 47 Different combinations of male and female weight groups influencing grainage parameters of muga silkworm *Antheraea assama* Ww.

Treatment	Cocoon Weight	Real Fecundity	3 DRF	Hatching Number	Egg Weight (Hatch x Weight)	Hatching %
F1 X M_1	4.67	173.33	138.67	164.00	1.20	94.63
F1 X M_2	4.57	168.33	143.67	161.00	1.18	95.65
F1 X M_3	4.71	176.67	140.67	167.67	1.23	94.91
F1 X M_4	4.85	180.33	138.00	170.33	1.25	94.46
F1 X M_5	4.88	178.00	135.33	169.00	1.24	94.95
F1 X M_6	4.97	171.33	144.33	164.67	1.21	96.14
F1 X M_7	4.75	182.67	151.00	172.67	1.27	94.53
F2 X M_1	5.11	190.33	152.27	181.27	1.33	95.23
F2 X M_2	5.19	191.33	153.07	182.70	1.34	95.49
F2 X M_3	5.31	194.00	154.73	181.43	1.33	93.52
F2 X M_4	5.44	196.00	156.80	187.86	1.36	94.67
F2 X M_5	5.40	190.00	152.00	182.12	1.34	96.01
F2 X M_6	5.26	186.67	149.33	178.29	1.30	95.23
F2 X M_7	5.47	200.33	160.27	193.12	1.42	96.40
F3 X M_1	5.59	217.33	173.87	204.26	1.50	93.97
F3 X M_2	5.65	219.67	175.73	206.98	1.52	94.22
F3 X M_3	5.72	218.00	174.40	206.27	1.51	94.62
F3 X M_4	5.82	222.00	177.60	209.48	1.54	94.36
F3 X M_5	5.88	223.00	178.40	212.37	1.56	95.23
F3 X M_6	5.96	226.67	181.33	215.67	1.58	95.15
F3 X M_7	5.77	218.67	174.93	211.78	1.55	96.84
F4 X M_1	6.09	219.33	175.47	208.24	1.53	94.96
F4 X M_2	6.15	221.67	177.33	209.72	1.54	94.61
F4 X M_3	6.42	227.00	181.60	212.93	1.56	93.80
F4 X M_4	6.32	224.00	179.20	213.32	1.56	95.23
F4 X M_5	6.38	225.00	180.00	217.73	1.59	96.77
F4 X M_6	6.46	230.33	184.27	218.58	1.60	94.89
F4 X M_7	6.27	220.67	176.53	213.19	1.56	96.60
F5 X M_1	6.55	239.00	191.20	228.64	1.68	95.67
F5 X M_2	6.96	246.67	197.33	233.75	1.71	94.77
F5 X M_3	6.67	242.67	194.13	231.10	1.70	95.24
F5 X M_4	6.86	245.00	196.00	232.47	1.71	94.88
F5 X M_5	6.71	240.67	192.53	229.26	1.68	95.26
F5 X M_6	6.79	240.33	192.27	227.33	1.67	94.59
F5 X M_7	6.86	246.33	197.07	236.13	1.73	95.89
F6 X M_1	7.04	248.33	198.67	238.76	1.75	96.14
F6 X M_2	7.18	247.00	197.60	234.53	1.72	94.97
F6 X M_3	7.36	247.33	197.87	235.55	1.73	95.24
F6 X M_4	7.39	250.00	200.00	234.34	1.72	93.73
F6 X M_5	7.44	248.00	198.40	233.05	1.71	93.96
F6 X M_6	7.30	251.00	200.80	233.53	1.71	93.06
F6 X M_7	7.38	252.33	201.87	242.91	1.78	96.27
F7 X M_1	7.51	248.00	198.40	236.18	1.73	95.24
F7 X M_2	7.58	251.00	200.80	236.31	1.73	94.15
F7 X M_3	7.66	251.00	200.80	237.29	1.74	94.53
F7 X M_4	7.71	256.00	204.80	241.40	1.77	94.29
F7 X M_5	7.82	257.00	205.60	247.12	1.81	96.16
F7 X M_6	7.85	256.33	205.07	244.13	1.79	95.25
F7 X M_7	7.90	258.33	206.67	243.73	1.79	94.34
Mean	6.28	222.76	178.38	211.74	1.55	95.04
S Em (±)	0.02	1.06	0.87	2.72	0.02	1.12
CD (P = 0.05)	**0.06**	**2.97**	**2.44**	**7.63**	**0.06**	**3.15**

Control : 230 (RF)

having non-significant variation with F_1 x M_1 (1.20g), F_1 x M_6 (1.21g), F_1 x M_3 (1.23g) F_1 x M_5 (1.24g) and significant variation with others.

It was observed that fecundity, hatchability and egg vigour were increased with increase cocoon weight. Moreover, extreme high female cocoon group (F_7) when utilized with extreme high (M_7) or higher male cocoon group (M_6) showed better performance.

4.4.5. Female cocoon weight groups and influence on grainage parameters :

Female cocoon weight groups were taken as extreme high (T_7 : 7.50-7.99 g), higher (T_6 : 7.00-7.49 g) high (T_5 : 6.50-6.99 g), medium (T_4 : 6.00-6.49 g), low (T_5 : 5.50-5.99 g), lower (T_2 : 5.00-5.49 g) and extreme low (T_1 : 4.50-4.99 g)and their influence on grainage parameters namely realized fecundity, upto three (3) days fecundity, egg vigour and hatchability in terms of hatching number were recorded in table 48.

4.4.5.1. On Fecundity:

Realised fecundity showed significant variations among the treatments Highest realized fecundity was observed form T_7 (246.22) having no significant variation with T_6 (244.80) and T_5 (239.90) and having significant variation with others. There observed no significant variation between T_3 and T_4. T_1 Showed lowest fecundity (173.33) followed by T_2 (190.80) and others (Table 48).

Fecundity upto three days showed non-significant variation (184.00-203.00) among T_4, T_5, T_6 and T_7. Non-significant variation was also observed between T_3 and T_4 (181-184) followed significantly by T_2 and T_1 (153-162).

So, from the realised fecundity standpoint T_5 to T_7 *i.e.* High to extreme high showed better performance having non-significant variation among them and form 3days laying standpoint T_4 to T_7 it medium to extreme high were the best groups having non-significant variation. T_1 and T_2 *i.e.* Extreme low and lower were in the same group for

Table 48 Female cocoon groups and their influence on grainage parameters of muga silkworm *Antheraea assama* Ww.

Treatment	Weight range of Female Cocoon (gm)	Average weight	Fecundity		Hatchability number	Weight of Egg
			Upto 3rd Day	Total		
T_1	4.50-4.99	4.77	153.00	173.33	150.80	1.12
T_2	5.00-5.49	5.27	162.00	190.80	160.60	1.19
T_3	5.50-5.99	5.73	181.00	217.14	170.00	1.26
T_4	6.00-6.49	6.32	184.00	223.50	190.00	1.41
T_5	6.50-6.99	6.77	201.00	239.90	203.40	1.51
T_6	7.00-7.49	7.37	203.00	244.80	205.20	1.52
T_7	7.50-8.00	8.01	203.00	246.22	208.00	1.54
Mean	-	**6.32**	**219.38**	**183.86**	**184.00**	**1.36**
S Em (±)	-	0.048	6.99	5.34	4.07	0.03
CD (P = 0.05)	-	**0.148**	**20.77**	**15.59**	**11.89**	**0.09**

both realised fecundity and upto 3days laying that were significantly lowest performing groups.

4.4.5.2. On egg vigour:

No significant variation was observed between T_5 to T_7 (1.51 to 1.54) but there highest performing group were significantly followed by others. T_1 and T_2 (1.12 g to 1.19 g) showed lowest egg vigour followed by T_3 (1.26 g) and T_4 (1.41 g) where the variation was significant.

4.4.5.3. On Hatchability:

On hatchability, the treatments showed the similar trend. T_5, T_6 and T_7 were the best performing groups (203.40 to 208.22) having non-significant variation followed significantly by T_4 (190.00) and others. No significant variation was observed in T_1 (150.80) and T_2 (160.60) but they were the lowest performing groups. However, non-significant variation was observed between T_2 and T_3 (170).

4.4.5.4. Co-relation studies:

The cocoon groups showed significant correlation coefficient (r) with fecundity and egg vigour at 5% level of significance and with hatchability at 1% level of significance (Table 49).

From regression studies, it can be said that 1.0 g increase in cocoon weight increased realised fecundity by 22.9583 numbers with 94% variation, upto three days laying by 16.5494 numbers with 94% variation, egg vigour by 0.1435 times with 95% variation and hatching number by 19.4055 number in 96% variation (Table 49).

Table 49 Correlation Study

		Cor. Coeff. (r)	Regression Equation	R^2	Mean ± SD
Fecundity	3rd Day	0.94*	Y = 79.2651 + 16.54937 x	0.8905	183.86 ± 20.26
	Total	0.94*	Y = 74.2876 + 22. 95833 x	0.8899	219.38 ± 28.13
Hatching Number		0.96**	Y = 61.1040 + 19.40548 x	0.9229	184.00 ± 23.39
Weight of egg		0.95*	Y = 0.4580 + 0.14350 x	0.9187	1.36 ± 0.17

*** significant at 5 % level of confidence ** significant at 1 % level of confidence**

So, from overall observation it can be said that T_5, T_6 and T_7 *i.e.* High to extreme high groups performed best with non-significant variation among them and T_1 and T_2 *i.e.* Extreme low and lower performed worst with non-significant variation among them for all the grainage parameters namely realized fecundity, laying upto three days, egg vigour and hatchability.

4.5 Short-term cold preservation of cocoon, moth and egg of muga silkworm:

4.5.1 Muga silkworm survivability and egg production during adverse months :

The rearing was conducted during adverse summer months namely June – July, July – August and August – September and subsequent grainage operations were done. Survivability reflected as ERR and egg production recorded as realised fecundity and hatchability were depicted in table 50.

4.5.1.1. Effective Rate of Rearing :

Effective Rate of Rearing (ERR percentage) varied significantly among the periods. ERR was highest during August-September (30.80%) followed by July - August (10.60%) and the lowest being from June – July (8.20%). Reflecting very poor survivability rate during June – July and July - August.

Table 50 Effective Rate of Rearing and egg production parameters during adverse Summer months of muga silkworm (*Antheraea assama* Ww.).

Seasons	ERR. No.	Realized Fecundity (no.)	Incubation Period (days)	Hatchability (%)
June-July	8.20	170.00	8.00	7.21
July-August	10.60	188.00	8.00	6.24
Aug.-Sept.	30.80	230.00	8.33	63.03
CD at 5%	**2.090**	**10.22**	**1.505**	**1.70**

4.5.1.2 Realised fecundity :

Significant differences were observed. Highest fecundity was observed during August –September (230.00) followed by July-August (188.00) and June – July (170.00). Fecundity was poor during June – July and July – August.

4.5.1.3 Hatchability :

There observed non-significant variation between June – July (7.21%) and July – August (6.24%). However, during August – September hatching percentage was significantly higher (63.03%).

Adverse weather condition prevailing during June – mid September reflected in poor rearing and grainage performance of muga silkworm which ultimately reflected in poor performance during October – November rearing. An attempt was been made to overcome this situation by short-term preservation of cocoon, moth and eggs.

4.5.2 Preservation of cocoon :

Cocoons from May – June commercial rearing were taken and preserved at 5^0C, 7^0C and 10^0C and the pupal period, moth emergence, coupling efficacy, fecundity and hatchability were recorded (Table 51 and 52).

4.5.2.1 Pupal period :

Significant variation was observed between the temperatures as well as between the preservation days. Irrespective of preservation temperature and periods female pupal period was higher than male pupal period. Pupal period recorded significantly longer at 5^0C than 7^0C and 10^0C for both male (24.68 days) and female (25.33 days) pupa. As the preservation period increased the pupal period increased with a maximum of 28.89 days in female and 28.00 days in male. On an average after a preservation period of 16 days having non significant variation with 17 days of preservation and having significant variation between 5^0C, 7^0C and 10^0C with highest pupal period of 29.67 days in male and 30 days in female at 5^0C.

4.5.2.2 Emergence percentage :

Emergence percentage was observed good upto 16 days preservation (73.33%) and at 7^0C (84.39%) or 10^0C (83.91%) having non-significant variation. Highest emergence percentage was observed at 10^0C with three four and five days preservation (96.00%) which was even higher than the control (90.33%). The lowest emergence percentage was also from 10^0C when preserved for 18 days (15.67%) followed by 10^0C and preserved for 17 days (32.67%).

4.5.2.3 Coupling efficacy :

Coupling efficacy was observed higher when preserved at 10^0C (84.44%) followed by 7^0C (71.12%) and 5^0C (66.54%). Coupling efficacy decreased with the increased period of

Table 51 Effect cocoon preservation at different temperature on pupal period and emergence percentage of muga silkworm (*Antheraea assama* Ww.)

Preservation Days	Pupal Period								Emergence %			
	Male				Female							
	5^0 C	7^0 C	10^0 C	Mean	5^0 C	7^0 C	10^0 C	Mean	5^0 C	7^0 C	10^0 C	Mean
1	18.67	18.67	18.33	**18.56**	19.67	19.33	18.67	**19.22**	88.19	90.67	92.00	**90.29**
2	19.67	19.33	19.00	**19.33**	20.67	20.00	19.67	**20.11**	88.33	89.00	92.67	**90.00**
3	20.33	19.67	19.67	**19.89**	21.33	21.00	21.00	**21.11**	90.33	93.67	96.00	**93.33**
4	21.67	21.33	21.00	**21.33**	22.33	22.33	22.00	**22.22**	92.33	94.33	96.00	**94.22**
5	23.33	22.33	22.33	**22.66**	23.67	22.33	22.33	**22.78**	91.00	92.67	96.00	**93.22**
6	24.33	24.00	22.67	**23.67**	24.67	24.33	22.67	**23.89**	89.33	92.00	93.67	**91.67**
7	25.00	24.67	24.33	**24.67**	25.33	25.00	24.67	**25.00**	88.67	91.00	93.33	**91.00**
8	25.33	25.00	24.33	**24.89**	25.67	25.33	24.67	**25.22**	85.00	87.67	90.00	**87.56**
9	25.33	25.33	24.33	**25.00**	26.00	25.67	25.00	**25.56**	82.33	86.00	90.00	**86.11**
10	25.67	25.33	24.67	**25.22**	26.33	25.67	25.33	**25.78**	82.00	84.00	89.33	**85.11**
11	25.67	25.33	25.33	**25.44**	26.33	25.67	25.67	**25.89**	81.33	83.67	90.00	**85.00**
12	26.33	25.67	25.33	**25.78**	26.67	26.33	25.67	**26.22**	80.67	82.67	89.33	**84.22**
13	26.67	26.33	25.67	**26.22**	27.33	27.00	26.33	**26.89**	80.33	82.33	89.67	**84.11**
14	27.00	26.67	26.33	**26.67**	27.67	27.00	26.67	**27.11**	79.33	80.67	89.33	**83.11**
15	28.33	27.67	26.33	**27.44**	29.33	28.33	26.67	**28.11**	74.33	78.00	89.67	**80.67**
16	29.67	28.33	26.00	**28.00**	30.33	29.00	27.33	**28.89**	69.33	72.00	78.67	**73.33**
17	29.33	28.00	25.67	**27.67**	30.00	28.67	26.33	**28.33**	66.67	71.00	32.67	**56.78**
18	29.33	27.67	25.33	**27.44**	29.67	28.33	25.67	**27.89**	51.67	61.67	15.67	**43.00**
Mean	**24.68**	**24.14**	**23.37**	24.06	**25.33**	**24.72**	**23.93**	24.66	**81.66**	**84.39**	**83.91**	83.32
Control	17.33	17.33	17.33	**17.33**	18.33	18.33	18.33	**18.33**	90.33	90.33	90.33	**90.33**
Temperature												
S Em (±)	0.08				0.10				0.21			
CD (P = 0.05)	0.21				0.28				0.58			
Days												
S Em (±)	0.19				0.25				0.52			
CD (P = 0.05)	0.54				0.69				1.46			
Interaction												
S Em (±)	0.33				0.43				0.92			
CD (P = 0.05)	0.93				1.20				2.53			

preservation, highest from one-day preservation (91.67%) and lowest from 18 days preservation (40.00%). Highest coupling efficacy was observed 95% by one day and two days preservation at 10^0C while the lowest was from 5^0C when preserved for 18 days (25%) followed by 7^0C preserved for 18 days (35%).

Table 52 Effect cocoon preservation at different temperature on coupling efficacy, fecundity and hatchability of muga silkworm (*Antheraea assama* Ww.).

Preser-vation Days	Coupling Efficacy				Fecundity				Hatchability			
	5^0 C	7^0 C	10^0 C	Mean	5^0 C	7^0 C	10^0 C	Mean	5^0 C	7^0 C	10^0 C	Mean
1	90.00	90.00	95.00	**91.67**	241.67	241.33	242.00	**241.67**	94.67	95.67	97.96	**96.10**
2	88.00	90.00	95.00	**91.00**	241.67	243.00	242.00	**242.22**	97.17	94.50	98.49	**96.72**
3	85.00	85.00	94.00	**88.00**	238.67	238.33	239.00	**238.67**	99.04	99.05	98.26	**98.78**
4	84.00	85.00	92.00	**87.00**	236.00	234.67	230.67	**233.78**	99.02	99.08	98.04	**98.71**
5	78.00	80.00	90.00	**82.67**	233.33	232.67	230.33	**232.11**	98.07	98.07	98.83	**98.32**
6	78.00	80.00	91.00	**83.00**	230.67	229.67	225.33	**228.56**	97.06	98.03	97.47	**97.52**
7	75.00	78.00	90.00	**81.00**	228.33	226.33	218.67	**224.44**	96.09	97.51	97.90	**97.17**
8	70.00	75.00	90.00	**78.33**	222.67	220.33	212.33	**218.44**	95.00	96.03	97.36	**96.13**
9	65.00	72.00	88.00	**75.00**	213.67	211.33	206.67	**210.56**	94.70	94.00	93.35	**94.02**
10	65.00	70.00	85.00	**73.33**	208.00	187.00	172.67	**189.22**	91.01	89.18	89.67	**89.95**
11	60.00	70.00	85.00	**71.67**	184.33	183.00	164.00	**177.11**	91.15	90.06	84.04	**88.42**
12	60.00	65.00	85.00	**70.00**	179.00	176.67	167.67	**174.45**	90.00	88.98	84.37	**87.78**
13	55.00	60.00	80.00	**65.00**	177.67	176.33	172.00	**175.33**	90.00	87.98	87.92	**88.63**
14	55.00	60.00	78.00	**64.33**	175.67	173.67	154.67	**168.00**	89.00	84.00	81.07	**84.69**
15	50.00	60.00	75.00	**61.67**	165.00	163.67	143.00	**157.22**	88.00	84.97	80.29	**84.42**
16	45.00	55.00	70.00	**56.67**	155.33	156.00	126.33	**145.89**	76.84	71.94	74.59	**74.46**
17	40.00	45.00	65.00	**50.00**	144.67	142.33	113.00	**133.33**	74.93	70.06	69.58	**71.52**
18	25.00	35.00	60.00	**40.00**	121.33	119.33	101.00	**107.22**	72.06	70.00	67.17	**69.74**
Mean	**66.54**	**71.12**	**84.44**	74.03	**201.68**	**198.72**	**190.53**	196.98	**91.17**	**89.87**	**89.20**	90.08
Control	96.33	96.33	96.33	**96.33**	244.33	244.33	244.33	**244.33**	98.40	98.40	98.40	**98.40**
Temperature												
S Em (±)	0.19				1.04				0.10			
CD (P = 0.05)	0.54				2.91				0.27			
Days												
S Em (±)	0.49				2.61				0.24			
CD (P = 0.05)	1.36				7.31				0.68			
Interaction												
S Em (±)	0.84				4.52				0.42			
CD (P = 0.05)	2.36				12.66				1.17			

4.5.2.4 Fecundity :

Fecundity was significantly higher when preserved at 5^0C (201.68) and when preserved for up to 3 days (242.22 to 238.67). However, upon interaction there observed no significant variation between 5^0C, 7^0C and 10^0C upto 5 days preservation (242.00 – 230.33). After 9 days preservation there observed significantly decreased fecundity at 10^0C and as a whole the fecundity decreased from 14 days preservation abruptly which was higher from 10^0C.

4.5.2.5 Hatchability :

Hatchability observed better when preserved at lower temperatures, 91.17% at 5^0C and 89.87% at 7^0C. Furthermore, hatchability was best (98.78% to 98.32%) when preserved for three, four and five days. Highest hatching percentage was observed at 7^0C preserved for four days (99.08%) having non-significant variation with 5^0C preserved for three days (99.04%) and four days (99.02%), 7^0C preserved for three days (99.05%) and 10^0C preserved for one to four days (97.96% to 98.01%) and having significant difference with others.

It was observed from the result that cocoon preservation at low temperature resulted in 27 days pupal period while the emergence percentage and coupling efficacy were better from 10^0C though the fecundity and hatchability were better from 5^0C and 7^0C. However, for higher number of hatched larva, requirement of higher number of emergence and higher number of coupling should be taken in account primarily.

4.5.3 preservation of adult :

Adults from May – June commercial rearing were taken and preserved at 5^0C, 7^0C and 10^0C and the coupling efficacy, fecundity and hatchability were recorded (Table 53).

4.5.3.1 Coupling Efficacy :

Significant variation was observed between three different temperatures. Coupling efficacy was found best at 10^0C (76.71%) followed by 7^0C (62.08%) and by 5^0C (55.46%). Coupling efficacy decreased with increased preservation days highest from one day preservation (86.67%) and lowest from 7 days preservation (16.67%). Moreover, at 10^0C beyond 5 days preservation the coupling efficacy decreased from 75% to 40% and at 5^0C and at 7^0C up to 3 days and up to 4 days adult could be preserved for better coupling efficacy.

4.5.3.2 Fecundity :

Fecundity was significantly higher from adult preserved at 5^0C (235.13) than 7^0C (228.38) and 10^0C (225.13). At the same time, fecundity decreased with the increased preservation days. However, there observed no significant variation in fecundity among the temperatures for one day and two days of preservation. There observed significantly better fecundity in 5^0C and 7^0C than 10^0C for rest of the days.

Table 53 Effect Adult preservation at different temperature on coupling efficacy, fecundity and hatchability of muga silkworm (*Antheraea assama* Ww.).

Preser-vation Days	Coupling Efficacy %				Fecundity Number				Hatching %			
	5^0 C	7^0 C	10^0 C	Mean	5^0 C	7^0 C	10^0 C	Mean	5^0 C	7^0 C	10^0 C	Mean
1	80.00	82.00	98.00	**86.67**	244.00	241.00	243.00	**242.67**	88.00	88.00	88.89	**88.30**
2	77.00	80.00	97.00	**84.67**	242.00	238.00	241.00	**240.33**	89.00	88.44	89.44	**88.96**
3	75.00	78.00	93.00	**82.00**	238.00	232.00	230.00	**233.33**	88.33	86.77	88.33	**87.81**
4	50.00	70.00	84.00	**68.00**	240.00	230.00	224.00	**231.33**	84.01	83.11	82.11	**83.08**
5	40.00	50.00	75.00	**55.00**	235.00	222.00	217.00	**224.67**	85.88	85.11	80.33	**83.77**
6	20.00	25.00	40.00	**28.33**	230.00	220.00	209.00	**219.67**	85.33	72.00	68.00	**75.11**
7	5.00	15.00	30.00	**16.67**	210.00	202.00	195.00	**202.33**	72.22	68.11	65.33	**68.55**
Mean	**55.46**	**62.08**	**76.71**	**64.75**	**235.13**	**228.38**	**225.13**	**229.54**	**84.97**	**82.32**	**81.18**	**82.82**
Control	96.67	96.67	96.67	**96.67**	242.00	242.00	242.00	**242.00**	87.00	87.00	87.00	**87.00**
Temperature												
S Em (±)	0.46				0.36				0.36			
CD (P = 0.05)	1.31				1.03				1.02			
Days												
S Em (±)	0.75				0.59				0.59			
CD (P = 0.05)	2.15				1.68				1.67			
Interaction												
S Em (±)	1.31				1.02				1.02			
CD (P = 0.05)	3.72				2.92				2.89			

4.5.3.3 Hatching percentage :

Hatching percentage observed better over control for first three days of preservation at any temperature, highest was on two days preservation and non-significantly from 5^0C (90.33%). Hatching percentage observed better at 5^0C than 7^0C and 10^0C for rest of the days.

It was observed from the results that though the fecundity and hatchability were better at 5^0C, coupling efficacy, the ultimate parameter for seed yield was better at 10^0C.

4.5.4 Preservation of egg :

Eggs of different age (24 hours, 48 hours 72 hours and 96 hours) were preserved at 4^0C, 6^0C, 8^0C and 10^0C for 3 days, 7 days, 12 days and 21 days and the parameters recorded were incubation period, delay of hatching and hatching percentage.

4.5.4.1 Incubation period :

Incubation period increased with the increased duration of preservation period, highest being from 21 days of preservation. Regarding cold temperature preservation, 10°C was found best for the 24 hours eggs, 8°C for 48 hours, 6°C for 72 hours and 4°C for 96 hours egg. Highest incubation period was found on 24 hours egg at 10°C for 21 days, which was 26.10days and lowest being from 72 hours eggs at 10°C when preserved for 3 days, which was 10.03 days.

Table 54 Effect of refrigeration at different temperature for different days on eggs of different days laying on incubation period of muga silkworm (*A. assama* Ww.)

Days	24 hours Egg				48 hours Egg				72 hours Egg				96 hours Egg			
	4°C	6°C	8°C	10°C	4°C	6°C	8°C	10°C	4°C	6°C	8°C	10°C	4°C	6°C	8°C	10°C
3	11.96	12.16	12.30	13.20	11.36	11.00	11.46	11.33	10.96	11.06	10.46	10.03	10.5	10.40	10.10	0.00
7	14.03	14.13	14.36	15.06	14.46	13.96	14.50	14.03	14.10	14.63	14.03	13.60	16.03	13.53	13.53	0.00
12	18.00	18.10	18.50	20.10	18.13	17.03	18.96	17.46	19.43	20.10	17.50	15.96	20.06	16.96	16.06	0.00
15	18.96	18.96	20.10	20.20	22.10	18.96	25.16	20.06	21.03	21.03	0.00	0.00	22.16	19.03	0.00	0.00
21	22.96	23.30	24.10	26.10	25.06	0.00	0.00	0.00	25.13	0.00	0.00	0.00	25.06	0.00	0.00	0.00

Contd…

CD at 5%: Egg laying x preservation days = **0.028**; Egg laying x temperature = **0.024**; Preservation days x temperature = **0.028,**
Egg laying x preservation temperature x preservation day = **0.512.**

However, no egg was hatched in different treatments which were at 10°C on 96 hours eggs for all the preservation days, on 72 hours eggs for 15 and 21 days preservation and 48 hours eggs for 21 days, at 8°C 72 hours and 96 hours eggs for 15 and 21 days preservation, 48 hours eggs for 21 days preservation and at 6°C 48 hours , 72 hours and 96 hours eggs for 21 days preservation. No harmful effect was observed for 4°C preservation. (Table 54)

4.5.4.2 Delay of hatching :

Control batch showed incubation period for 7 days and after 7 days eggs were hatched. So the delay of egg hatching was calculated by deducting these 7 days from the total incubation period of different treatments and results were furnished in Table 55.

Table 55 Effect of refrigeration at different temperature for different days on eggs of different days laying on days delay of hatching of muga silkworm (*Antheraea assama* Ww.).

Days	First day laying				Second day laying				Third day laying				Fourth day laying			
	4^0C	6^0C	8^0C	10^0C	4^0C	6^0C	8^0C	10^0C	4^0C	6^0C	8^0C	10^0C	4^0C	6^0C	8^0C	$10\ ^0C$
3	4.96	5.16	5.30	6.20	4.36	4.00	4.46	4.33	3.96	4.06	3.46	3.03	3.50	3.40	3.10	0.00
7	7.03	7.13	7.36	8.06	7.46	6.96	7.50	7.03	7.10	7.53	7.03	6.60	9.03	6.53	6.53	0.00
12	11.00	11.10	11.50	13.10	11.13	10.03	11.96	10.46	12.43	13.10	10.50	8.96	13.06	9.96	9.06	0.00
15	11.96	11.96	13.10	13.20	15.10	11.96	18.16	13.06	14.03	14.03	0.00	0.00	15.16	12.03	0.00	0.00
21	15.96	16.30	17.10	19.10	18.06	0.00	0.00	0.00	18.13	0.00	0.00	0.00	18.06	0.00	0.00	0.00

Contd...

CD at 5%: Egg laying x preservation days = **0.118**; Egg laying x temperature = **0.073**; Preservation days x temperature = **0.113**, Egg laying x preservation temperature x preservation day = **1.487**.

Delay of hatching followed the same trend of incubation period i.e. for 24 hours laying at 10°C, for 48 hours 8°C, for 72 hours 6°C and 96 hours 4°C showed better delay of egg hatching. Simultaneously delay was found higher with increased preservation days, highest being from 21 days, but hatching was only found for 24 hours laying at any temperature. In case of 48,72and 96 hours laying only at 4°C the eggs were hatched when preserved for 21 days. Highest delay for 19 days were obtained from 24 hours laying for 21 days preservation at 10°C followed non-significantly by 72 hours laying preserved for 21 days at 4°C (18.13 days), 48 hours and 96 hours laying for 21 days preservation at 4°C (18.06 days) and significantly by others. Days delay was minimum when eggs of 72 hours were preserved for 3 days at 10°C (3.03 day) having non-significant differences with layings of 48hours, 72 hours and 96 hours eggs for 3 days at any temperature (3.10-4.46 days).

4.5.4.3 Hatching percentage :

Hatching percentage, the ultimate reflection of cold preservation, was depicted in Table 56 and in the control batch hatching percentage is 82%. Only the eggs of 24 hours laying for 21 days preservation at 8°C(98.93%)and 10°C(90.10%) showed better hatching percentage, but eggs of other hours were failed to show better hatching percentage which was below 50%. Moreover, 24 hours laying for 21 days at 4 °C and 6°C also performed poorly which was only 50%.

Table 56 Effect of refrigeration at different temperature for different days on eggs of different days laying on percentage of hatching of muga silkworm (*Antheraea assama* Ww.).

Days	First day laying				Second day laying			
	4^0C	6^0C	8^0C	10^0C	4^0C	6^0C	8^0C	10^0C
3	99.46	99.50	99.50	90.13	99.90	99.56	98.33	99.66
7	99.30	99.30	99.56	89.30	99.73	99.63	99.60	99.76
12	99.66	99.53	90.26	88.90	99.83	99.73	99.70	69.70
15	99.70	99.70	99.70	89.96	99.36	99.83	99.43	59.90
21	50.30	50.10	98.93	90.10	49.80	0.00	0.00	0.00

Contd…

Third day laying				Fourth day laying			
4^0C	6^0C	8^0C	10^0C	4^0C	6^0C	8^0C	10^0C
98.80	99.63	99.60	99.83	99.56	99.56	80.16	0.00
98.10	99.73	99.72	99.46	80.16	80.36	80.06	0.00
98.50	99.56	20.00	20.06	80.03	79.36	20.03	0.00
98.66	98.73	0.00	0.00	19.93	19.46	0.00	0.00
39.93	0.00	0.00	0.00	20.13	0.00	0.00	0.00

CD at 5% : Egg laying x preservation days = **0.132**; Egg laying x temperature = **0.065**;

Preservation days x temperature = **0.092**,

Egg laying x preservation temperature x preservation day = **11.510**

When eggs of the 96 hours were preserved for 15 days , no egg was hatched at 8^0C and 10^0C ,at the same time 4^0C and 6°C when eggs were hatched, the hatching percentage nearly 20% only. The result was also same for 12 days preservation of 96 hours eggs at 8^0Cand of 72 hours laying both at 8^0C and 10^0C. Better performances (99.90 to 88.90%, having non-significant difference) were obtained from most of the other treatments excepting 12 and 15 days preservation of 48 hours laying at 10^0C and 96 hours laying at any temperature for 7 and 12 days preservation and 3 days preservation at 8^0C.

It was observed from the result that 10^0C temperature was optimum for delayed hatching up to 48 hours old eggs should be considered for preservation and the performance from 21 days preservation was better enough with out any deleterious effect.

4.5.5 Continuous preservation of cocoon, adult and egg :

To avoid rearing during June – August reflecting poor supply of seed during October – November refrigeration of cocoons from previous commercial crop (May – June) was done at 10^0C and subsequently emerged adults were refrigerated at 10^0C and then adults were utilized for coupling and the egg laid by the preserved female were collected after 12 hours, 24 hours, 36 hours and 48 hours and refrigerated at 10^0C for 7 days, 15 days, 21 days and 30 days. The hatchability was recorded.

4.5.5.1 Effect of cocoon preservation on adult emergence :

4.5.5.1.1. Pupal period

In natural condition (Control), pupal period was found 17.33 days for male and 18.33 days for female. No adult was emerged after 18 days. After short term preservation of seed cocoon at 10 ± 1^0C, the pupal period has been lengthened for both male and female. It was observed that longer the preservation days longer the pupal period upto 18^{th} day. Longest pupal period was observed for 17 days preservation which was 9.33 days and 8.67 days more over control for male and female respectively. However, there observed no significant difference between 11 to 18 days in male and 13 to 18 days in female.

4.5.5.1.2. Emergence Percentage

Emergence percentage was found higher over control than preserved for more than 2 days to 8 days. However, 90 to 96% emergence was observed upto 15 days preservation and in control. A drastically decreased emergence was observed after 16 days (78.67%) when it was 32.67% in 17th days and only 15% in 18 days preservation and after that emergence was nil.

Table 57 Effect of seed cocoon preservation at 10±1^{0}C on pupa period and emergence percentage of muga silkworm (*Antheraea assama* Ww.)

Cocoon Preservation Days	Pupal period after preservation		Emergence %
	Male	Female	
1	18.33	18.67	92.00
2	19.00	19.67	92.67
3	19.67	21.00	96.00
4	21.00	22.00	96.00
5	22.00	22.33	96.00
6	23.67	23.67	93.67
7	24.33	24.67	93.33
8	24.33	24.67	90.00
9	24.33	25.00	90.00
10	24.67	25.67	89.33
11	25.33	25.67	90.00
12	25.33	25.67	89.33
13	25.67	26.33	89.67
14	26.33	26.67	89.33
15	26.33	26.67	89.67
16	26.67	27.00	78.67
17	26.67	27.00	32.67
18	26.00	26.33	15.67
Control (Fresh)	17.33	18.33	90.33
CD at 5%	**1.432**	**1.444**	**0.739**

Taking emergence percentage as well as delayed pupal under consideration, adult moths from 15 days preserved cocoon was selected for adult preservation.

4.5.5.2 Effect of adult preservation on egg production :

Effect of adult preservation was recorded as coupling efficacy, realized fecundity and hatchability. (Table 58)

4.5.5.2.1. Coupling efficacy :

No Significant variation was observed between the coupling efficacy of fresh coupling (control) (96.67%) and upto 3 days of adult preservation (90%-96.67%). Significant variations were observed in all other cases and from 6 days and above the coupling efficacy were observed very low.

Table 58 Effect of adult preservation at 10±1^{0}C on coupling efficacy, fecundity and hatchability of muga silkworm, (*Antheraea assama* Ww).

Adult Preservation Period	Coupling efficacy (%)	Fecundity (No.)	Hatchability (%)
1 day	96.67	242	88.66
2 days	96.78	240	89.40
3 days	90.00	225	87.16
4 days	80.00	220	80.18
5 days	70.00	210	78.30
6 days	36.67	200	65.28
7 days	23.33	189	63.18
Fresh x Fresh (Control)	96.67	245	88.79
CD at 5%	**9.53**	**3.53**	**8.48**

4.5.5.2.2 Fecundity

As the preservation day increased fecundity decreased. Highest fecundity was observed in control (245) having non-significant difference with 1 day and 2 days preservation, lowest being from 7 days (189).

4.5.5.2.3. Hatchability

Hatchability also followed the similar trend. Significant highest hatchability was obtained from control (88.76%) and upto 3 days of adult preservation (87.16%-88.66%) followed by preservation of 4 and 5 days (78.30%-80.18%) adult preservation. Significantly lowest hatchability was observed from 7 days preservation (63.18%).

From overall results, it can be said that eggs from 5 days preserved adult can be selected for preservation as far as delayed hatching is concerned.

4.5.5.3 Effect of egg preservation on hatchability:

Eggs obtained from 5 days adult preservation was collected after 12 hrs., 24 hrs., 36 hrs. and 48 hrs. and preserved for 7, 15, 21 and 30 days. Incubation period, days delayed (control : 8 days) hatching percentage were recorded (Table 59).

4.5.5.3.1. Incubation Period

Incubation period could not be recorded for 30 days preservation as no larva was hatched. Highest incubation periods was observed when 12hrs./24hrs. eggs were preserved for 21 days (32.33 days) followed by 36hrs. for 21 days (31.33 days). Lowest incubation period was observed when 12hrs./24hrs. eggs were preserved for 7 days (18.33 days).

Table 59 Effect of seed preservation of different hours of laying at 10±1^{0}C on incubation period and hatchability percentage of muga silkworm (*Antheraea assama* Ww.).

Hrs. after laying	Preservation period (days)	Incubation period (days)	Days delayed	Hatching %
12 hours	7	18.33	10.33	86.33
	15	27.00	19.00	85.00
	21	32.33	24.33	42.75
	30	-	-	-
24 hours	7	18.33	10.33	83.76
	15	27.67	19.67	73.30
	21	32.33	24.33	70.28
	30	-	-	-
36 hours	7	18.67	10.67	79.33
	15	28.33	20.33	70.67
	21	31.33	23.33	60.33
	30	-	-	-
48 hours	7	19.33	11.33	75.67
	15	24.33	16.33	68.33
	21	29.33	21.33	49.67
	30	-	-	-
CD at 5%				
Hrs. after laying		**0.263**	**0.263**	**0.201**
Preserve Period		**0.228**	**0.228**	**0.151**
Hrs. after laying x Preserve period		**0.457**	**0.457**	**0.604**

4.5.5.3.2. Days delayed

When 12hrs./24hrs. eggs were preserved for 21 days hatching delayed for 24.33 days followed by 36 hrs. egg preserved for 21 days (23.33 days) and by 48 hrs egg preserved for 21 days (21.33). Lowest delay was observed from the eggs of 12hrs./24hrs. when preserved for 7 days (10.33 days).

4.5.5.3.3. Hatching Percentage :

Hatching percentage showed significant difference. Highest hatching percentage was found from the eggs of 12hrs. and preserved for 7 days and lowest from 12hrs. preserved for 21 days. Eggs of 24 hrs. when preserved for 21 days showed 70.28% hatching while in the eggs of 36 hrs. preserved to 21 days showed 60.33% hatching. However 48 hrs. egg when preserved for 21 days showed only 49.67% hatching.

CHAPTER - V

DISCUSSION

5.1 Seasonal Influences on Grainage Performances of Muga Silkworm :

Antheraea assama Ww. is a highly heterogeneous unique and semi-domesticated strain of Saturniidae family of Lepidopteran insect, endemic to Assam, adjacent foothills of Meghalaya, Nagaland, Arunachal Pradesh, and Mizorum; but even during favourable season 30% of the farmers fail to make full utilization of the available plantation due to shortage of seed cocoon and only quality muga silkworm seed in sufficient quantity will make possible the way for restoration of the past glory of muga culture of Assam (Samson and Barah, 1989). Findings of Sahu *et al.* (1998) also supports this view, according to them due to low yield of seed cocoons Regional Muga Research Centre cannot produce the required quantity of cocoons for production of targeted dfls for supplying to the commercial rearers. Recently Central Silk Board trying to explore muga culture in non-traditional belt like Cooch Behar and Jalpaiguri district, districts under terai region of West Bengal. Here also the principal constraint is poor supply of quality seed for full utilization of available plantation.

Seasonal variation in certain important parameters pertaining to grainage of muga silkworm in relation to temperature and relative humidity in all the six crops in Assam has been studied over five years by Sahu *et al.* (1998); profound seasonal effect of temperature and relative humidity have been observed in incubation period, hatching percentage, pupal period, coupling and oviposition.

All these reports of earlier works have stimulated to make an year-round investigation on seasonal influence on grainage performances of muga silkworm for the further evaluation in the unique agro-climatic region of the terai in Cooch Behar district with a view to bring a success in muga culture.

An analysis of the results shows that influences of environmental factors have strong reflection on fecundity and hatchability. During October – November the potential fecundity (276.60), realised fecundity (274.70) and upto 3rd days realised fecundity (217.80) are highest among the treatments which follows the performance during April – May (potential fecundity 248.20, realised fecundity 244.80 and upto 3rd days realised fecundity 200.70). During November – December and February – March the performance of egg laying in terms of potential fecundity (242.60 and 231.50

respectively), realised fecundity (238.70 and 228.00 respectively) and upto 3rd days realised fecundity (188.30 and 192.50 respectively) are better. However, October – November and November – December are the main commercial crop rearing season where silk production is the prime objective. The seed production season for the supply of seed during those main commercial crop-rearing seasons is August – September where the egg laying performance is below the above mentioned periods (potential fecundity 227.90, realised fecundity 216.30 and upto 3rd days realised fecundity 169.70 respectively). The low potential fecundity during August – September is may be due to high temperature and humidity and the less realized fecundity is due to highly significant egg retention (11.60).

Hatching percentage during October – November (97.64), November – December (96.52) and February – March (94.24) is quite satisfactory but the seed crop rearing during April – May for 2nd commercial rearing during May – June is not successful enough as the hatching percentage is very poor (42.45 %). The main seed crop-rearing season also suffers not only from low fecundity but also from low hatching percentage (60.05 %).

From the correlation studies of these observations confirm that temperature is the prime influencing extrinsic factor regarding fecundity (-0.99) and light period regarding hatchability (-0.99). Increase in temperature decrease the fecundity during August – September while increasing light period decreases the hatching percentage during August – September as well as during April – May.

As the grainage operation during April – May and August –September is the primary task for successful commercial rearing during May – June and October – November respectively, the performance during these seed crop-rearing seasons should be investigated properly. The extrinsic factors show strong negative influence on fecundity and hatchability during these two seasons and strong positive influence during October – November and February – March. Moreover, the seed multiplication seasons in summer months *i.e.* July – August and winter months *i.e.* during January – March also suffer badly due to negative influence of temperature and light period on grainage activity during these periods.

These performance should be investigated in the light of the effect of extrinsic factors on intrinsic factors for seed production taking the influence of host plants under consideration.

The intrinsic factors namely pupal period, emergence period, mating period, oviposition period and incubation period are influenced by the environmental factors. Shorter pupal period (17.65 days – 17.90 days) are observed during summer months while longer pupal period are observed during winter periods (23.80 days – 29.40 days). Pupal periods from 18.30 days – 21.40 days are observed during spring, autumn and early winter months namely February – M arch and mid October – m id Decemb er. Emergence period is higher in summer and lower in winter. Normal mating period is higher in autumn, winter and spring months while the mating period is shorter during summer months. Oviposition period is very short (3.90 - 4.40 days) during summer months and incubation period lengthens during winter months. Strong negative correlation exists between temperature and pupal period (-0.99) while light period has negative correlation with oviposition period (-0.95). However, there exists correlation between all the environmental factors and intrinsic factors as well as intrinsic factors and grainage parameters which ultimately reflects the poor performance during April – May and August – September.

Som plant shows better performance over soalu plant for both the intrinsic factors and grainage parameters during all the seasons, still fails to improve the grainage performance during April – May and August – September.

October-November has been observed the best season for seed production. But according to Assamese calendar this is the main commercial crop growing season. For stock maintenance some cocoons can be selected. Cocoons from August-September rearing are used for egg production to supply eggs during main commercial crop growing season. Though a single female can lay 216 eggs, actually 130 hatched larvae can be obtained for rearing. Another seed crop rearing season, April – May, to supply eggs during second commercial crop rearing season shows 245 eggs laid by a single female but as hatchability is very poor (42%), 104 eggs can be obtained from a single female. However, February – March (pre seed crop) shows 230 laying per female of which 216.20 eggs were hatched (94%). This difference is may be due to seasonal influence as winter months show better hatching performance as stated by Ochieng- Odero (1992) though potentiality is less due to outdoor rearing during winter as well as poor quality leaf. During June-July though potential fecundity is high (217), realized fecundity is less (177) due to egg retention inside female body might be due to high temperature, humidity and abnormal rainfall during that period (Biswas and Ray, 2005). High temperature and humidity affects the hatchability which might be the cause of obtaining poor number of hatched larva during April – May, June – July and August – September as mentioned by Thangavelu *et al.* (1988) who opines that decrease activity of sperm beyond 32^0C prevent during those period affects fertility reflecting in low hatching percentage.

So, from the over all observations it can be said that the conventional seed crop production seasons *i.e.* August – September and April – May are low productive. After critical observation it can be concluded that February – March can be utilized as a seed crop-rearing season instead of April – May that can be exploited as commercial crop rearing season instead of May – June. At the same time, October – November may be utilized as seed crop rearing season instead August – September and the main commercial crop rearing season may be shifted from October – November to November – December.

These slight modifications of rearing schedule of Assamese calendar may be suitable for terai region of West Bengal where micro climatic variation with Assam exists. Further more, to maintain the rearing schedule of Assam (if the modification is not possible), manipulation of environmental factors for seed production or utilization of cold preservation technology can be investigated.

Now, for economic success as well as synchronized rearing, selection of days up to which eggs can be collected from all the egg laying period (5-6 days) is necessary. It has been revealed from results that in all the seasons female lays highest number of eggs on first day which declines gradually. During all the seasons except June – July almost 85% eggs are laid within first three day, however, hatching percentage is above 90% within these days during October-November and February - March only. Only 43 eggs out of 278 eggs are laid during last three days of which 36 eggs are hatched during October - November. So, collection of last three days can be avoided as 232 quality eggs can be ascertained within 3 days. Likewise, during February – March only 36 eggs out of 230 eggs are laid during last 3 days of which 31 eggs are hatched. So, 193 quality eggs can be obtained within 3 days. During other seasons also, where egg layings are up to 5 days the laying of last two days ranges between 35 – 40 eggs and hatching percentage is very poor (35 – 48 %) and even nil during June – July.

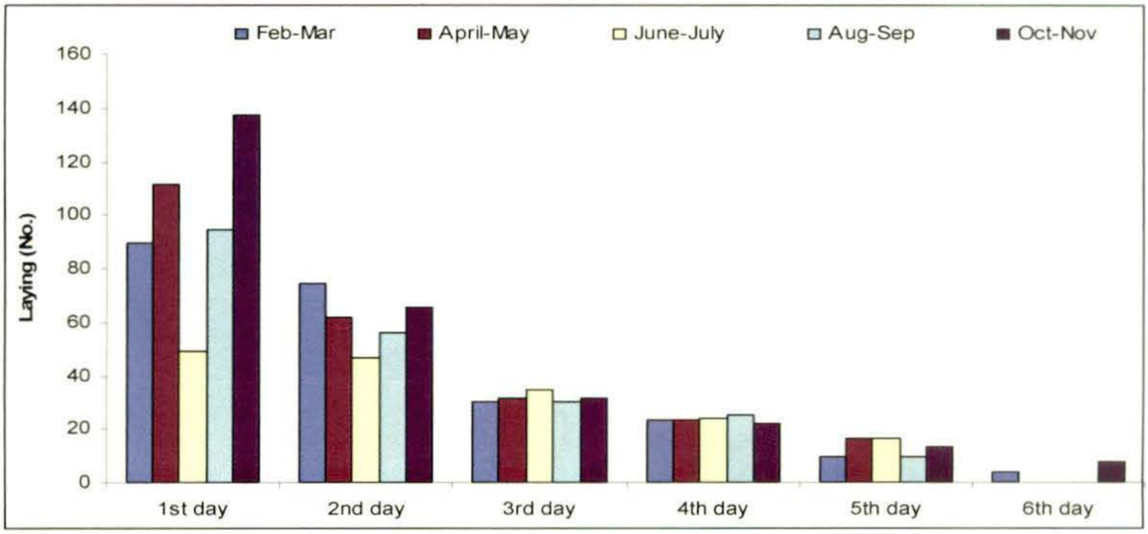

Figure 18 Effect of day and season on egg laying

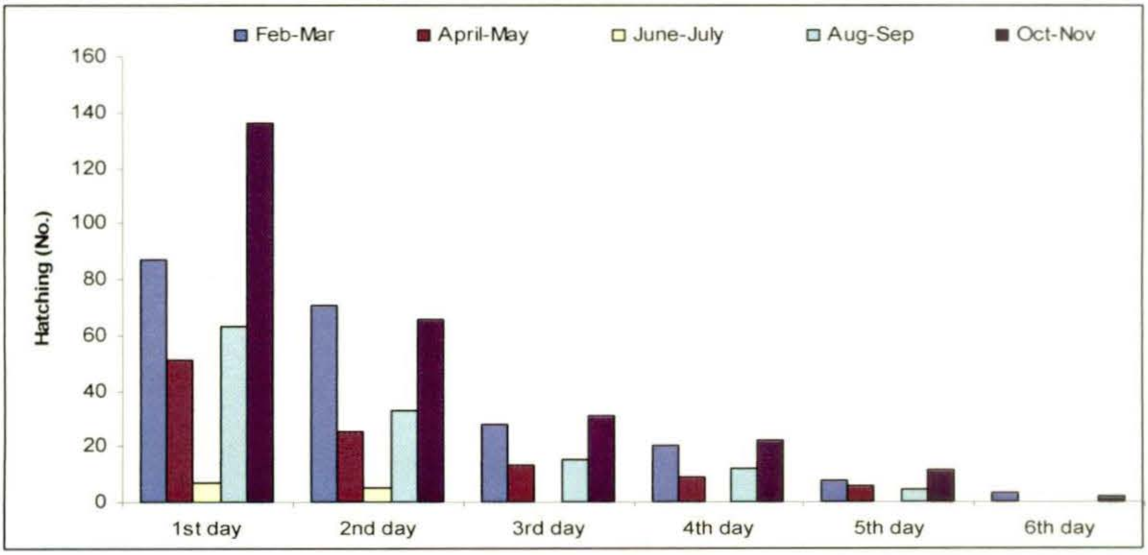

Figure 19 Effect of day and season on egg hatching

During two seed crop rearing seasons, namely April - May and August – September, 70% eggs can be collected from 3 days laying which were 205 and 181 eggs respectively of which only 89 and 111 eggs are hatched respectively. Upon collection of total laying only 104.00 and 130.00 hatched larva can be obtained during April – May and August – September respectively which are far lower than the collection of first 3 days during October – November and February – March to supply seed for commercial rearing. Moreover, this ultimately reflects in rearing hazards showing uneven rearing length and longer cocoon harvesting period as well as poor crop yield (Biswas and Ray, 2005).

So, from overall discussion it can be concluded that for supply of quality seed during commercial rearing collection of eggs from first three days (fig 18 and 19) will be effective for successful economic and synchronous rearing and it can be further suggested that February – March and October - November can be utilized as seed crop rearing period to have enough number of seeds during commercial rearing during March – April and November – December instead of May – June and October – November, which ultimately strengthens the suggestions made after observing seasonal influence on muga silkworm rearing and grainage operation.

5.2. Manipulation of abiotic factors to standardize the optimum combination responsible for seed production with higher hatchability :

Seasonal influence on muga silkworm rearing reveals that October – November is the main commercial crop rearing season which suffers badly due to poor seed supply. The seed crop rearing of October – November is August – September and after grainage operation the eggs produced as well as the hatchability of the eggs are poor. Moreover, the poor survivability rate of larvae during August – September increases the problem of low seed supply to a great extent. The second commercial crop-rearing season, May – June, though it is recommended from present study to utilize April – May as 2nd commercial season, also suffers in the similar manner. The seed produced during April – May is not sufficient enough as the survivability rate of larvae during March is poor. Furthermore, the hatchability of eggs from April – May grainage operation is very poor, even less than August – September.

This critical situation of poor seed supply during two main commercial seasons can be solved to some extent by manipulating the environmental factors namely temperature, relative humidity and photo period during egg incubation to improve hatching percentage of the laid eggs. The environmental factors cannot be manipulated during rearing as muga silkworm is in out door condition. Keeping this under consideration only a shorter but most important period of indoor grainage operation from egg incubation to hatching can be manipulated to improve the hatching percentage of the egg with an objective to increase the hatched larva for commercial rearing.

Manipulation of temperature from 15^{0}C to 35^{0}C reflects that during April – May where normal temperature is 26.65^{0}C manipulation of temperature to 25^{0}C increases the hatchability from 44.79% to 59.03% and during August – September when the normal temperature is 28.92^{0}C, manipulation of temperature to 25^{0}C increases the hatchability from 63.03% to 68.67%.

Relative humidity from 65% to above 90% manipulation shows that during April - May when normal RH is 68%, manipulation of RH to 75% increases the hatchability from 44.79% to 48.21% and during August – September when the normal RH is 77.5%, manipulation of RH to 75% can only level the normal hatching percentage while others fail.

While the temperature plays a crucial role in hatchability, where lower temperature upto 25^{0}C have significantly improving effect and beyond that level have adverse effect, relative humidity shows less intense effect while 85% and above 90% showed an adverse effect of humidity. This findings are in conformity with Barah *et al.* (1993) working on muga silkworm.

Combined effect of temperature and RH manipulation shows a significant improvement of hatching percentage over control as well as over individual effect of temperature and RH during both the seasons. During April – May, when 44.79% is the normal hatching percentage and 25^{0}C temperature individually improves it up to 59.03% as well as 75% RH improves up to 48.21%, the combined effect of temperature and RH increases it up to 73.33% where the temperature and RH are 25^{0}C and 75% respectively. 25^{0}C temperature with 85% RH also improves the hatching percentage up to 65%, surprising to note that 85% RH alone shows the adverse effect on hatching percentage. During August – September also, the combined effect of temperature and humidity improves the hatching percentage from 63.03% in normal condition or 68.67% at 25^0C temperature (75% RH maintain as per normal) to 85% where the manipulated temperature and RH are 25^0C and 75% respectively. At 25^0C, 85% RH and 65% RH also improve the hatching percentage (88% and 75% respectively). 72% hatching percentage is also obtained from manipulated the temperature at 20^0C and RH at 75%.

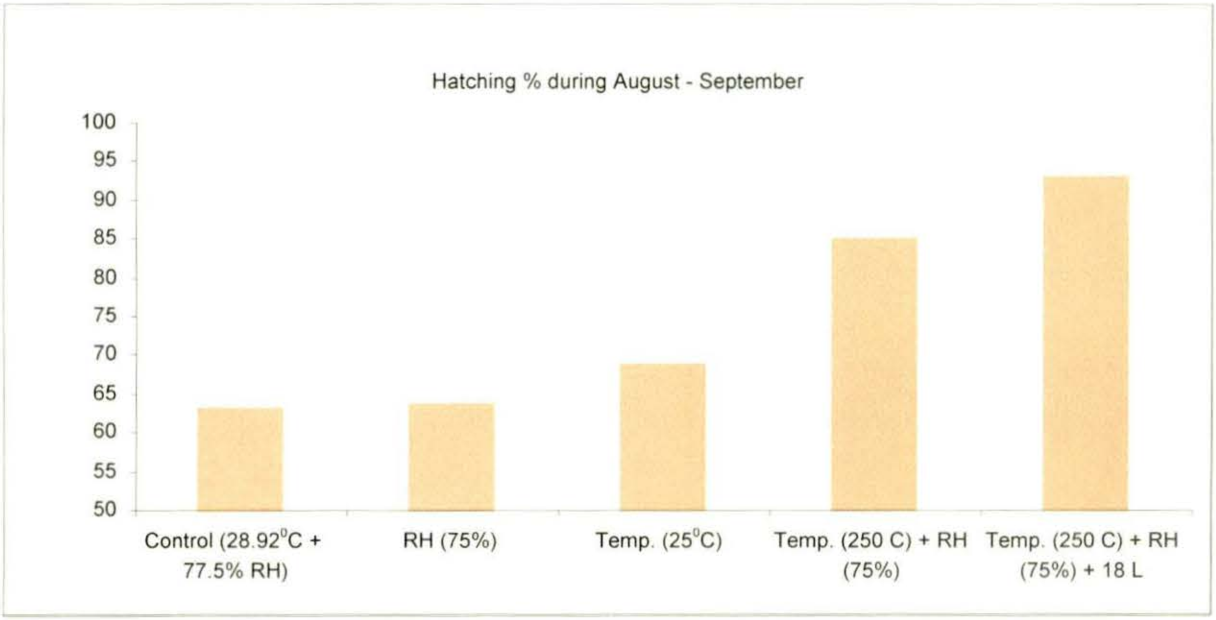

Figure 20 Effect of manipulation of temperature, relative humidity and photoperiod on
hatching percentage during August – September.

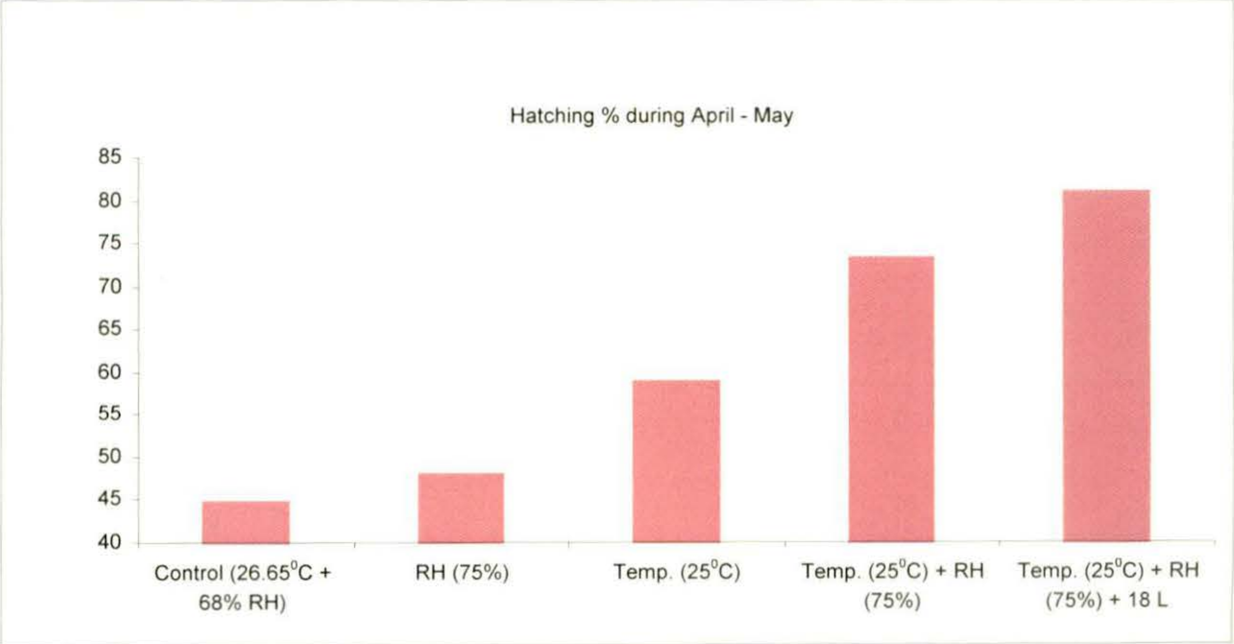

Figure 21 Effect of manipulation of temperature, relative humidity and photoperiod on hatching percentage during April - May.

Photoperiod influences the uniform and perfect hatching; eggs should be incubated under proper light regimes for better hatchability (Meenal *et al.,* 1994). The combination of temperature and RH are again manipulated with photoperiods. During April – May, where combined effect of temperature and humidity increases the hatching percentage from 44.79% to 73.33%, 12 to 18 hour light improves it with a highest of 81.07% where the manipulated temperature humidity and photoperiod are 25^{0}C, 75% and 18L. During August – September also, photoperiod from 12 hour to 18 hour improves the hatching percentage. The highest hatching percentage is 92.97% where the manipulated temperature, RH and photoperiods are 25^{0}C, 75% and 18L. 25^{0}C temperature along with 85% RH at 18L condition hatching percentage improves up to 91.54% also.

It can be recommended that manipulating 25^{0}C temperature with 75% RH and 18 hours light regimes can improve the hatching percentage to a great extent having clear conformity with the findings of Barah *et al.* (1993) according to whom 26^{0}C temperature with 85% RH is the incubation schedule to get 85% hatching and in the present findings adding the photoperiod at 18L condition (with 25^{0}C temperature and 75% RH) 93% hatching can be achieved in contrast to 63% hatching in normal condition during August – September (Figure 20) and 81.07% hatching can be achieved in contrast to 44.79% hatching in normal condition during April – May (fig. 21).

During incubation, embryonic development is influenced by temperature. Higher the temperature shorter is the incubation period. Relative humidity also influences the incubation period in similar manner but it is a less intense effect. The present findings is in conformity with Barah *et al.* (1993) working on muga silkworm and Upadhyay and Gaur, (2002) working on *Bombyx mori.*

5.3. Synchronization of male and female moth emergence and mating behaviour studies for quantitative improvement of quality seed production :

Male moth emerges earlier than the female moth. Therefore, synchronization has been proved principal constraint for egg production because asynchronous male and female moth emergence decreases coupling efficacy (Thangavelu *et al.,* 1988).

In the present investigation after seed crop rearing commercial grainage operation during March – April and September - October has been done taking 16 possible combinations of mating for four days. The coupling efficacy of freshly emerged male and female is always better than any other combination. However, up to three days old male can be coupled fresh female showing good coupling efficacy. Fecundity and hatchability decrease after two days combination.

This observation is in conformity with the findings of Rath (1998) according to whom natural mating is not possible beyond 4 days and both mating success and fertility are considerably low when mating occurs beyond 2nd day.

To overcome the situation of poor seed production short-term preservation of male and female moths have been done at 10 ± 1^0C and utilized in 16 possible combinations. Coupling efficacy has been improved from 71.27% to 90.60% in March – April and from 46.40% to 65.54% in September - October as a whole. One day preserved female shows higher coupling efficacy, fecundity and hatchability than fresh coupling. Moreover, the coupling efficacy of 3 days preserved female are also above 80%. Fecundity also increases after preservation, however, distinctive variation in hatching percentage is not so pronounced. It has been also observed that when preserved females take more crucial role than male.

The present findings are in agreement with the earlier work made by Singha *et al.,* (1994), according to whom the fecundity in general has no significant difference after refrigeration of females up to 6th day. Similar observations were also made by Tazima (1962), Ayuzama *et al.* (1972) and Jolly (1983) show that when virgin female moths are preserved for three days at 5^0C temperature reflects no significant variation. According to Gowda (1998) fecundity is reduced significantly after three days of refrigeration of female moth.

From the overall observation it can be said that during both the seasons one day preserved female coupled with fresh male or one day preserved male improves the coupling efficacy as well as fecundity and hatchability.

The hatched larva (hatching yield), the ultimate output of grainage operation, calculated (coupling efficacy x fecundity x hatching percentage) higher (23010.39) in one day preserved female coupled with fresh male than the calculated hatched larva from natural mating of similar age male and female with out preservation (1st day male coupled with 2nd day female) showing 20485.44 hatched larva and also better than even the best performing couple (fresh male and female) in normal condition showing 22221.60 hatched larva during March – April (Fig. 22).

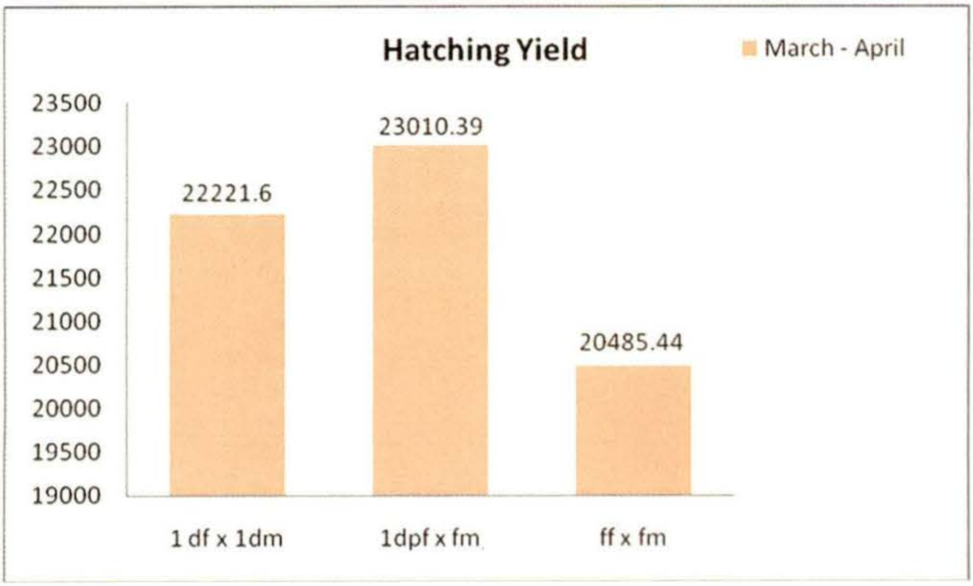

Figure 22 Comparative analysis of hatching yield in normal and preserved condition (best combination) during March – April.

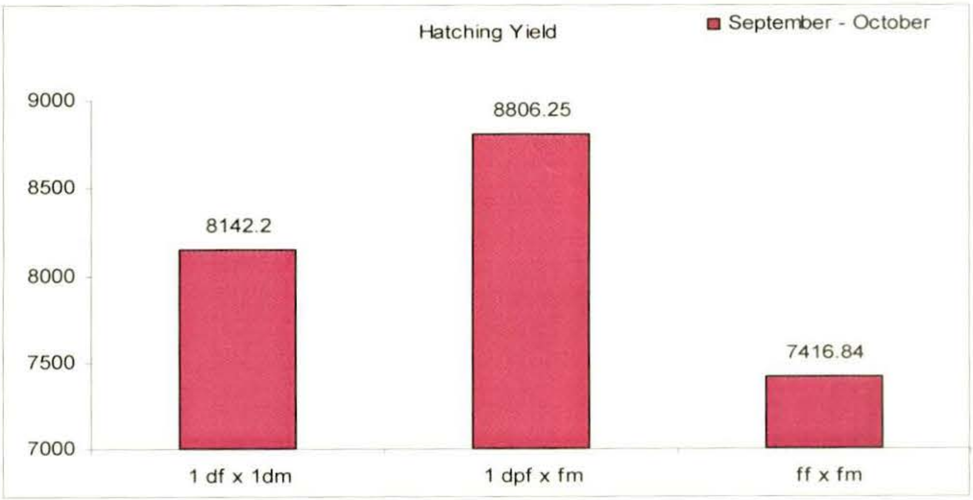

Figure 23 Comparative analysis of hatching yield in normal and preserved condition (best combination) during September - October

During September - October, the calculated hatched larva/100 coupling is also better by preservation method where the best combination (one day preserved female coupled with fresh male) shows 8806.25 number than the same age with out preservation (7416.84 in 1st day male coupled with 2nd day female) and also better than the best performing couple in normal condition (fresh male and female) showing 8142.20 hatched larva (Fig. 23).

Finally when a total of the four days coupling in normal condition and preserved condition are compared the actual reflection comes out. During March – April the calculated hatched larva/100 coupling is 20640.46 by preservation method which is more than double of the same in natural condition (9721.14) and during September - October, the difference is greater *i.e.* 7298.45 in preserved condition and 2827.62 in normal condition (Fig. 24).

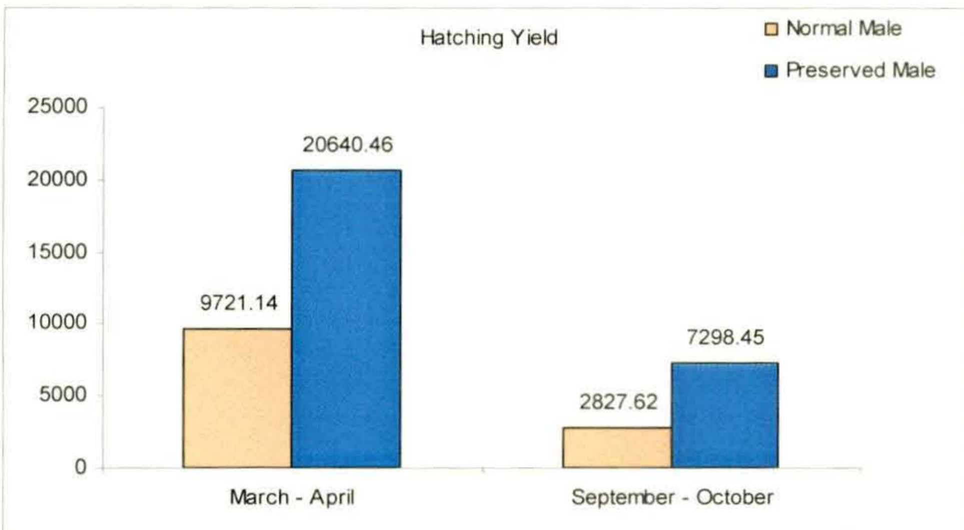

Figure 24 Comparative analysis between normal condition and preserved condition (in total of four days)

So, it can be concluded that preservation of male and female moths for 3 days and synchronization in different combinations can improve the quality seed yield to a greater extent.

Another way to overcome the constraint of asynchronous moth emergence reflecting less number of seed production is the repeated mating by exploiting the same male. For this, the optimum hours of mating should be recorded. So, in the first experiment, effect of different mating hours on egg laying and hatching have been recorded (Table – 34). Non-significant results obtained from mating hours reflects that upto 12 hours mating any duration from second hour is sufficient for successful fertilization and egg laying which confirms the observations of Samson and Barah (1989), according to whom 3-5 hours mating is sufficient. From this observation it can be suggested that minimum mating hours can be exploited and the decoupled male can be utilized for repeated mating. However, in practice mechanical injury may damage both the male and fertilized female during decoupling within 5 hours. Moreover, mating duration of 7 hours shows highest fecundity and hatchability, though the differences with others are not significant. So, mating duration can be suggested 7 hours optimum for successful mating, egg laying and hatching.

In the next experiment, repeated mating has been conducted exploiting the males for a maximum of four (4) times during March-April (Table 37) and of six (6) time during September - October (Table 38) because it has been reported that female fertility in silkworm depends upon their male mates (Sidhu *et al.,* 1967). During both the seasons though potential fecundity of the female are nearly same, repeated mating changes the egg laying and hatching. From repeated mating exploiting males upto 4 times during March-April shows that utilization of male upto 3 times have no harmful effect on fecundity as well as hatchability. During September-October also, no significant variation has been observed between the egg laying of females mated with males utilized for the 2nd, 3rd and 4th time and after that decreases significantly and hatching also decreases from single mating to 5th time mating, however, no egg hatched from 6th time utilization. Therefore, utilization of male upto 4th time during this season is effective in terms of egg laying and hatching.

Both the results have clear conformity with Benchamin *et al.* (1990), according to them in *Bombyx mori* the fecundity is comparable in the first 4 mating but reduces in 5th and 6th mating and with Ojha *et al.* (1996) trying the repeated mating in *Antheraea mylitta* where they have been found that females lay eggs even when mated with 4 x males. Repeated mating lead to inadequate discharge of spermatic fluid and result in reduced fecundity (Sidhu *et al.,* 1967). This is also reflected in terms of reduced laying and fertility percentage in the present study. Earlier studies also indicate that viability of eggs is not affected significantly upto four mating of male moths (Subramanyam, 1982).

So, in mugaculture, as synchronization of male and female is one of the principal constraints of egg production, the problem can be overcome through repeated exploitation of male moth upto four times prior to main commercial crop rearing season and upto three times before second commercial rearing by artificial coupling for seven hours which will ultimately supply higher number of quality eggs to the farmers.

5.4. Characterization of seed Cocoon

Preliminary screening of seed cocoon, based on cocoon characters namely weight, length and width, shows that when cocoon weight is selected, weight ranged between 6.50 to 8.50 g. (T_3 and T_4) gives better performance. Cocoon length between 4.50 cm. 5.50 cm (T_3 and T_4) performs better and cocoon width between 6.30 cm to 7.10 cm. shows better performance in terms of realized fecundity, laying upto three days, egg vigour and hatchability.

To perform the seed cocoon screening, one of the estimators should be selected, if possible for the farmer's point of view. With regard to that the seed cocoons are grouped under four groups namely light where weight, length and width considered as 4.50 g to 5.50 g, 3.50 cm to 4.00 cm and 5.50 cm to 5.90 cm respectively, average where weight, length and width are 5.50 to 6.50 gm, 4.00 cm - 4.50 cm and 5.90 cm to 6.30 cm respectively, moderate where weight, length and width are 6.50gm 7.50gm, 4.50 cm to 5.00 cm and 6.30 cm to 6.70 respectively cm and Heavy where weight, length and width are considered as 7.50g – 8.50g, 5.00 cm – 5.50 cm and 6.70 cm. to 6.90 cm. Results show that heavy cocoons perform best followed by moderate, average and light cocoons for all the grainage parameters.

Correlation studies showing the correlation coefficient (r) between various cocoon measurements and various grainage parameters indicate that for fecundity all the estimators have significant correlations, for hatchability weight and width have significant correlation and for egg vigour, the significant correlation has been with width only. Based on the regression equations obtained estimated value of fecundity, hatchability and egg vigour have been worked out and deviation from the mean observed fecundity, hatchability and egg vigour shows that all the estimated grainage parameters based on the weight of the cocoon is the nearest estimated values to the observed value by the least deviation. Hence, weight of the cocoon has been considered as the best estimate even though the other parameters also gives the near estimates of the observed fecundity, hatchability and egg vigour. Miller *et al.* (1982) while establishing the relation between pupal size and egg production in the case of *Antheraea polyphemus* (Gramer), indicate the pupal weight as the best estimator of the number of matured eggs. Kotikal *et al.* (1989) on *Samia Cynthia ricini* and Badhera (1992) on *Antheraea mylitta* (Drury) also have suggestion to consider pupal weight as the best estimator of fecundity. The present findings on *Antheraea assama* Westwood are in agreement with the previous study made in the other saturniids.

The distribution pattern of different weight range in male and female cocoon is reflective of normal distribution and indicates predominance of medium weight range in both male and female followed by low, lower, extreme low, high, higher and extreme high in male and low, high, lower, higher, extreme high and extreme low in female. Nagalakshmamma (1987) in *Samia Cynthia ricini* and Dubey *et al.* (2005) in *Antheraea myllita* also have similar observation.

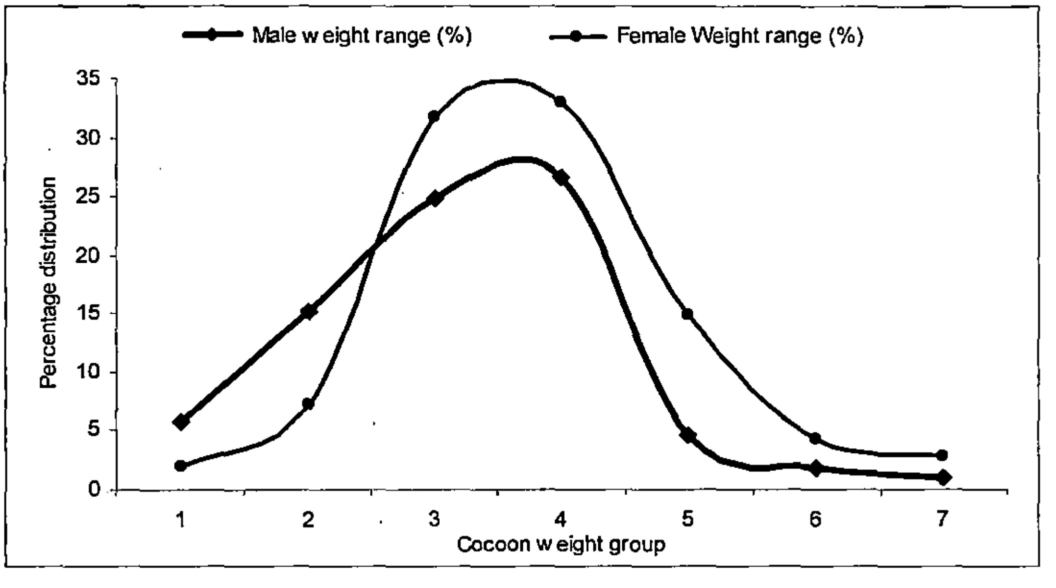

Figure 25 Sex-wise distribution pattern of seed cocoon weight group

The male and female cocoon weight classified in different groups indicate that 26.72 percent population of male cocoon weight falls in medium group which varies between 4.00-4.49 g whereas 33 percent population of female cocoon weight varies in the range of 6.00-6.49 g. The confidence interval at 95 percent reveals that the average male cocoon ranges maximum between 4.26 - 4.36 g and average female between 6.29 - 6.43 g in normally distributed population. It is evident from the normal distribution graph (figure 25) that 20.11 percent population of male and female seed cocoons both overlap each other between low, medium and high groups.

Hence, it is inferred that proper care should be taken while segregating this 20.11 percent population of male and female seed cocoons, in other groups the chances of error is negligible. Dubey *et al.* (2005) have the similar findings on tasar silkworm with 38% critical male and female population.

Cocoon weight instead of pupal weight should be selected for seed cocoon selection for farmers view taking under consideration. For that relationship between cocoon and pupal weight has been studied and correlation studies indicates highly significant and positive correlation between pupal and cocoon weight in both the sexes.

From the regression equations, it is possible to predict and estimate the pupal weight from cocoon weight. It indicates that in case of male cocoon an increase of 0.91 g in pupal weight raises the cocoon weight 1.0 g with 98% variation, whereas in case of female cocoon an increase of 0.98 g in pupal weight increases the cocoon weight by 1.0 g with 99% variation. The pupal weight is in fact the determiner / estimator of fecundity as mentioned by Kotikal *et al.*, 1989; Badhera *et al.*, 1992 and Dubey *et al.*, 2005. As there exists a highly significant positive correlation between pupal weight and cocoon weight, it may be wise to select cocoon weight as estimator of seed cocoon selection for the farmers.

Realised fecundity, hatchability and egg vigour increases with the increased cocoon weight. Extreme high female (F_7) x extreme high male (M_7), extreme high female (F_7) x higher male (M_6), higher male (M_6) and female (F_6), high female (F_6) x medium male (M_5) show better performance which reflects female cocoon weight is more determining factor than male and the combinations of high weight groups (male and female) perform better having clear conformity with Dubey *et al.* (2005) working on *Antheraea mylitta.*

From the above discussion, it can be said that cocoon weight is the best estimator of seed cocoon selection for seed (egg) production. Moreover, female cocoon is the ultimate estimator as male cocoons have non-significant positive relationship with quality egg production.

Keeping this view under consideration seven groups of female seed cocoons have been selected on the weight basis namely extreme low (T_1 : 4.50 - 4.99 g), lower (T_2 : 5.00 - 5.49 g), low (T_3 : 5.50 - 5.99 g), moderate (T_4 : 6.00 - 6.49 g), high (T_5 : 6.50 - 6.99 g), higher (T_6 : 7.00 -7.49 g) and extreme high (T_7 : 7.50 - 7.99 g). Non-significantly best performing groups are extreme high, higher and high, which means that female cocoons weighting above 6.50 g can be selected for seed production. Non-availability of these cocoons moderate and low cocoon groups *i.e.* female cocoons weighing in between 5.50 g and 6.49 g can be selected for quality seed production.

These results support the earlier investigations of Shamachary *et al.* (1980), Gowda *et al.* (1988) and Shaheen *et al.* (1992) on *Bombyx mori* ; Nagalakshmamma (1987) and kotikal *et al.* (1989) on *Samia cynthia ricini* (eri silkworm); Miller *et al.* (1982) on *Antheraea polyphemus* and Badhera (1992) and Dubey *et al.* (2005) on *Antheraea mylitta.*

5.5. Short-term cold preservation of cocoon, moth and egg of muga silkworm:

For the success of sericulture industry, proper supply of silkworm egg (seed) is essential. The hatching period of eggs must coincide with the availability of suitable leaves (Upadhyay and Pandey, 2000). Muga culture in particular needs sufficient supply of seed during commercial rearing which is far below the target (Sahu *et al.,* 1998 a, b). Main commercial rearing seasons (October – November) suffer badly due to poor supply of quality seed. Because the seed crop rearing fails (August – September) due to poor seed supply from pre seed crop rearing (June – July). From the observation during June – September rearing and grainage operations it has been found that the hatching percentage of eggs coming from June – July rearing as well as July – August rearing is very poor which is almost below 10 percent. Though during August – September the hatching percentage is high (63%) but this rearing lacks acute shortage of hatched larva from June – July.

This situation calls an investigation whether there is any possibility to skip the rearing during June – August. Therefore, the hatching of larvae has to be controlled, accelerated or postponded by artificial treatment under the refrigerated condition (Upadhyay and Pandey, 2000).

Short-term cold preservation of cocoon at 5^0C, 7^0C and 10^0C shows lengthening of the pupal period in all the temperatures which gradually decreases with the increase of temperature. Significantly moth emergence as well as coupling efficacy is better at 10^0C though fecundity and hatchability are higher from the females emerged as well as coupled after refrigerating at 5^0C and 7^0C.

From the standpoint of more number of hatched larvae, 10^0C temperature is optimum for short-term preservation of cocoon as the emergence percentage and coupling efficacies are high (figure 26) which is of clear conformity with the findings of Anderwartha *et al.* (1974) who suggest to follow 10^0C as preservation temperature globally. Thangavelu *et al.* (1985) also have better results of cocoon preservation at 10^0C at high altitude (2590 mt.).

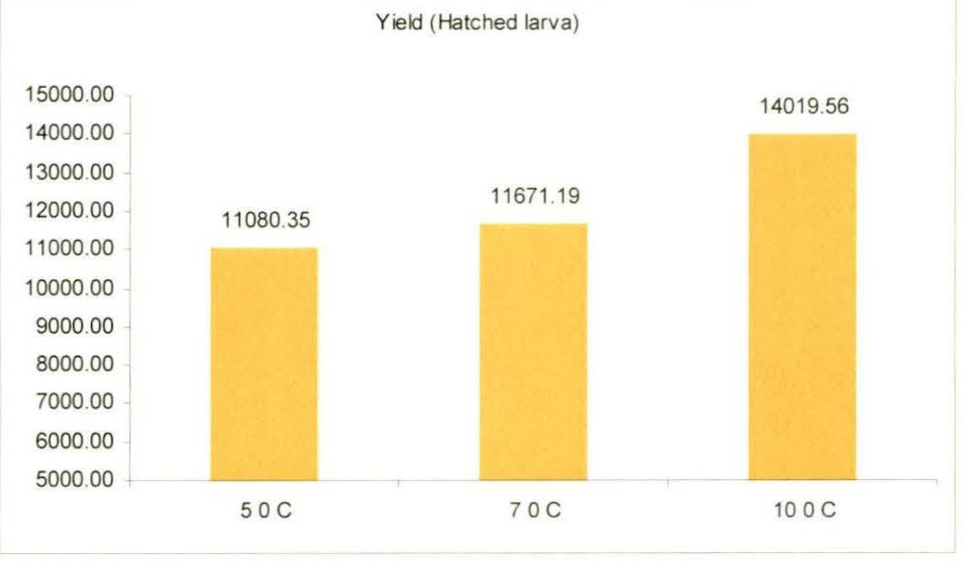

Figure 26 Effect of adult preservation on yield (hatched larva/100 coupling)

Several studies by Bora (1998) and Khanikor and Dutta (1998) also have positive observations by cold preservation from 5 – 12^{0}C.

One day cold preservation of adult at 5^{0}C, 7^{0}C and 10^{0}C shows significantly better fecundity and hatchability than control. But the coupling efficacy of the adult is significantly lower when refrigerated at 5^{0}C and 7^{0}C than refrigeration at 10^{0}C which ultimately reflects in lower number of hatched larvae (figure 27). So, from the standpoint of higher number of hatched larva, 10^{0}C temperature can be used for preservation of adult.

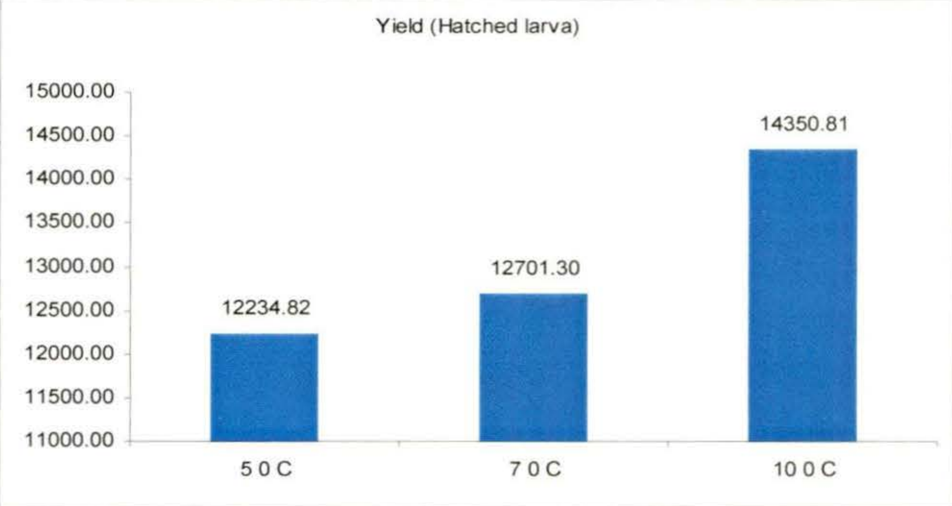

Figure 27 Effect of cocoon preservation on yield (hatched larva/100 coupling)

According to Tazima (1978) and Jolly (1983) *Bombyx mori* moths can be refrigerated at 5^{0}C for a minimum period of 7 days (for male) and 3 days (for female) for better fecundity and hatchability. In further study by Singh *et al.* (1994) refrigeration at 5^{0}C beyond 5 days should be avoided. The present study also shows the similar trend. However, at 10^{0}C temperature the muga moth can be refrigerated for 7 days with out any deleterious effect. Moreover, the coupling efficacy is also higher from the moth refrigerated at 10^{0}C which ultimately gives higher number of hatched larvae than from 5^{0}C or 7^{0}C.

The present investigation on egg preservation is based on two important aspects – age of egg and preservation temperatures as both the parameters have combined effect on hatching. Among the four age group considered (24 hours, 48 hours, 72 hours and 96 hours) eggs of 24 hours performed best in respect to delayed hatching with higher hatching percentage.

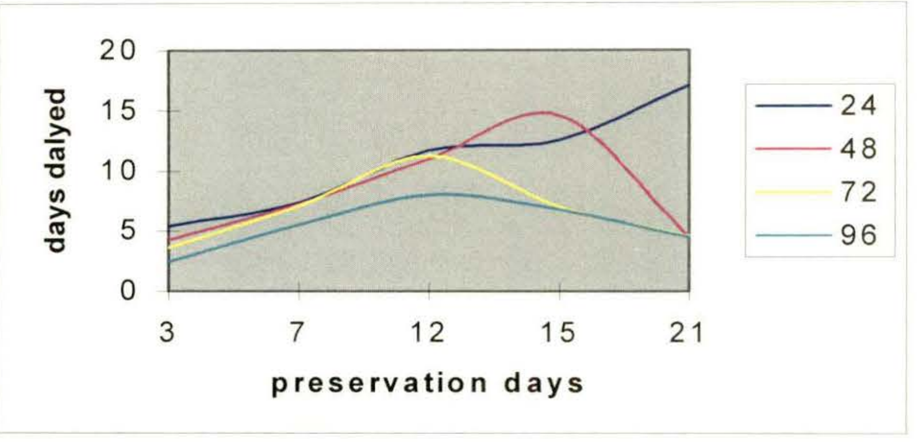

Figure 28 Effect of preservation on delayed hatching

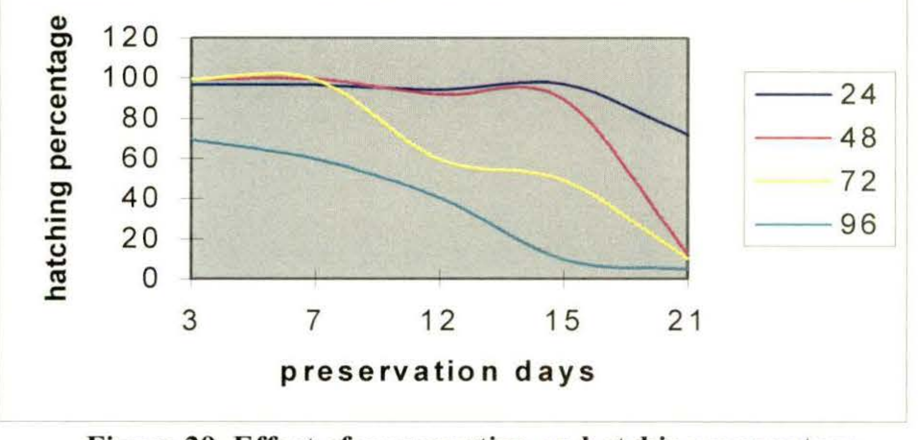

Figure 29 Effect of preservation on hatching percentage

When compared with the normal incubation period of 7 days, all the preservation period from 3 days to 21 days show longer incubation period, highest being from 21 days. Eggs of 24 hours when preserved for 21 days, hatch after 26.10 days which is 19.10 days more than normal condition and hatching percentage is also better (99.10%) than in normal condition (82%). Among all the temperature stress condition (4, 6, 8 and 10^0C), 10^0C is the optimum for 24 hours egg, 8^0C for 48 hours old, 6^0C for 72 hours old and 4^0C for 96hours old. Therefore, from the result it can be said that higher the age of eggs, higher the temperature stress required for successful cold preservation (Figure 28 and 29).

Moreover, as the age of the eggs progress preservation period become shorter. For example a minimum of 15 days for 48 hours egg and a maximum of 12 days for 96 hours eggs (Figure 30 and 31).

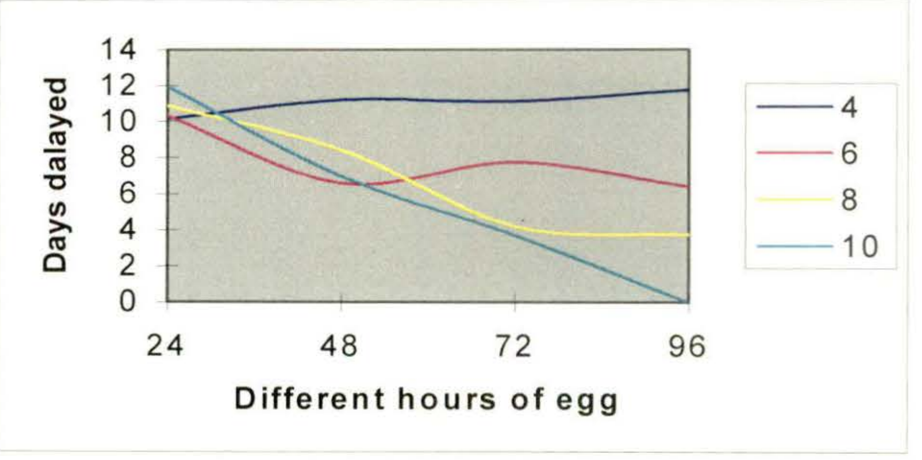

Figure 30 Effect of different hours of egg on delayed hatching

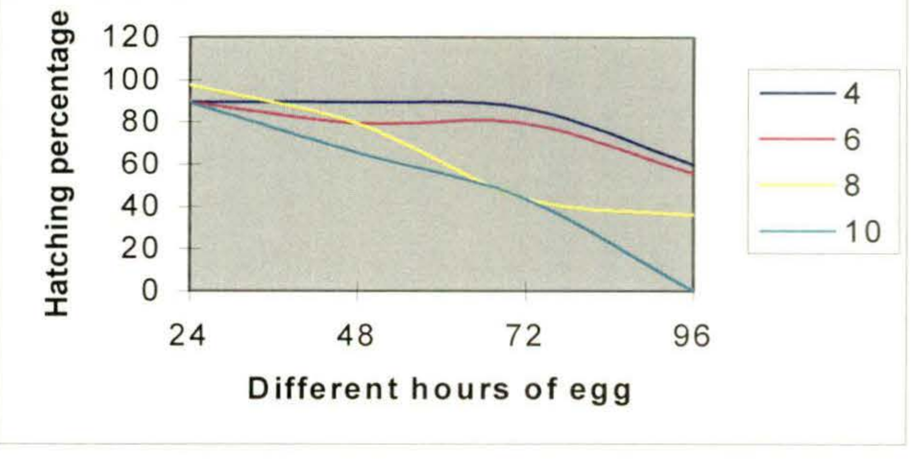

Figure 31 Effect of different hours of egg on hatching percentage

Result reflects that if 48 hours old eggs are necessary for preservation, 15 days preservation at 8^0C shows 18 days delayed hatching with higher hatching percentage. A delayed hatching with high hatching percentage of two weeks can be done by 72 hours eggs when preserved for 15 days at 6^0C. Delayed hatching (9-13 days) with satisfactory hatching percentage can be obtained from 96 hours eggs at 4^0C when preserved for a maximum of 12 days. The results have in clear conformity with the extensive studies by Dutta *et al.* (1972) on *Bombyx mori* where they observed that eggs incubated for shorter periods (up to 36 hours) are able to withstand preservation for longer period in comparison to eggs incubated for a longer period and then subjected to low temperature preservation.

So far as muga silkworm egg preservation is concern, low temperature stress on eggs can be exploited to control hatching period as and when needed. 24 hours old egg at 10^0C preserved for 21 days can delay hatching of 19 days having no deleterious effect on hatching percentage. Moreover, for older eggs longer preservation period have adverse effect on hatching and also needs higher temperature stress to get positive performance, Singha *et al.* (1998), on muga silkworm also have the similar findings where according to them cold preservation of 36 hours eggs can delay the hatching up to 36 days.

Keeping the results obtained from present experiment i.e. refrigeration of cocoon, moth and egg can delay the hatching under consideration, the attempt has been made to avoid rearing during June to August reflecting poor supply of seed during main commercial season (October – November) by refrigerating the cocoon from previous commercial crop (May – June), the subsequent adult and the eggs laid by them at 10^0C.

From the result it can be said that 15 days cocoon preservation from preceding commercial crop rearing can delay the moth emergence for 10 days, subsequent adult moth preservation for 5 days show almost no deleterious effect on fecundity and hatchability. The eggs thus obtained if preserved after 24 hours for 21 days can delay the hatching for 24 days. These results have conformity with the earlier findings of Khanikar and Dutta, (1998); Biswas and Ray, (2003), Singh *et al.* (1998) though exploration of only one stage for preservation at much lower than this experiment (10 ± 1^0C) has been made. The eggs thus brushed will be reared for supply of seed for commercial rearing. The grainage performance was also observed satisfactory.

So, by maintaining the schedule and preservation package collecting the cocoons from commercial crop of May – June the adverse seasons can be avoided as well as only 35 paisa/dfl. additional expenditure is required to supply adequate amount of healthy seed to the farmers for main commercial crop rearing during October – November. Additional electrical expenditure calculated for 20,000 dfl seed for commercial rearing which can be affordable (Table 60).

Table 60 Additional expenditure : (as electricity charge)

Input			
Cocoon Preservation (2500 cocoon)	15 days	180.00/day x 15	2700.00
Adult Preservation (90% Emergence) (@ 2200)	5 days	540.00/day x 5	2700.00
Egg Preservation (70% coupling & 210 fec.) @ 1000 dfl. Total electricity charges (Rs. 3.00 per unit)	21 days 6345.00	45.00/day x 21	945.00
Output			
Seed crop rearing dfl (having 70% hatching, 30% ERR and 230 realised fecundity)		20,000 dfl. Seed	
Additional expenditure (6345.00, 20,000) or 32 paise @ 35 paise/dfl.			

Finally, by short-term cold preservation at 10 ± 1^0C a package of practice regarding the schedule of muga silkworm rearing can be formulated to overcome the environmental stress investigating all the loop and holes including the economic investigations in the following manner.

Table 61 Schedule of preservation for successful seed production

Cocoon Collection	**Commercial Crop Rearing**	:	**May-June**
	Spinning	:	9th June
Preservation	Cocoon Preservation at 10 ± 1^0C	:	14th June
	Moth Emergence	:	6th July
	Moth Preservation at 10 ± 1^0C	:	6th July to 11th July
	Coupling and egg laying	:	12th July to 15th July
	Egg preservation at 10 ± 1^0C	:	13th July to 16th July
	Egg hatching	:	14th August to 17th August
Seed Crop Rearing	Seed crop rearing	:	14th August to 10th September
	Moth Emergence	:	29th September
	Coupling and egg laying	:	30th September to 3rd October
	Brushing for commercial rearing	:	8th October to 11th October
Main commercial rearing		:	**From 9th October**

The success of this experiment can able to provide a schedule of rearing for better supply of seed during the main commercial crop rearing during October – November (Table 61).

CHAPTER - VI

SUMMARY

An investigation was carried out in Cooch Behar district of West Bengal to standardize seed (egg) production technologies of muga silkworm, *Antheraea assama* Westwood. Attempts were made to identify the seasonal influence on seed production and hatchability with special reference to host plant effect as well as to standardize the optimum combinations of key abiotic factors responsible for production of better quality and productivity of seed with higher hatchability in order to harvest better yield of commercial cocoon crop at desired level, to standardize techniques towards synchronization of male and female moth emergence as well as to standardize mating behaviours in view to manipulate them in production of quality eggs with higher hatchability, to characterize seed cocoons for practical use during commercial crop rearing for better quantity of quality seed and to standardized seed preservation technologies to overcome the seasonal adversity.

Muga silkworm rearings were conducted during nine (9) different periods of a season namely, February-March, April-May, May-June, July-August, August-September, October-November, November-December, December-February and January-March on two principal host plant namely Som (*Persea bombycina*) and Soalu (*Litsea polyantha*) and after harvesting cocoons subsequent grainage operations were done in the laboratory. Seeds for rearing were collected from Extension Centre, Cooch Behar, Central Silk Board. Influence of seasons were observed on grainage parameters like potential fecundity, realized fecundity, fecundity upto three days, egg retention within the female body, hatching number and hatching percentage. Manipulation of temperature, relative humidity and photoperiod, the key abiotic factors, were done taking four temperature regimes namely 15^0C, 20^0C, 25^0C and 30^0C, four relative humidity regime namely 65%, 75%, 85% and above 90% and 6L, 9L, 12L, 15L and 18L as photoperiod in Environmental Test Chamber for optimization of environmental factors. For synchronization of moth emergence both the normal and cold preservation condition were explored. For normal condition cocoons were allowed to emerge upto 4 days and allowed to couple in 16 possible combinations and for cold preservation of adult moth after emergence upto 3 days at 10 ± 1^0C in BOD were done and allowed to couple in 16 different combinations. To find out the optimum period of coupling for successful fertilization of eggs, male moths were allowed to mate for 11 different durations from 2 hours to 12 hours. After standardization of mating hours, subsequently another experiment was undertaken to determine the mating times : multiple coupling capacity of male moths. In this experiment males were exploited upto six (6) times during September-October and upto 4 (four) times during March-April and egg laying, retention and hatchability were taken as key parameters. For selection of seed cocoons, preliminary screening was done on the basis of female cocoon weight, length and diameter named as light, average, moderate and heavy and their individual as well as combined reflection on fecundity, hatchability and egg vigour were the key parameters studied. After preliminary screening, cocoons were grouped under seven weight ranges separately for male and female with a same limit of weight. The groups were extreme low, lower, low, medium, high, higher and extreme high. Distribution patterns of weight range percentage were calculated. After emergence, fresh males and females were utilized for mating. Altogether 49 combinations along with one control batch (randomly selected cocoon) were selected and parameters like fecundity, hatchability and egg vigour were recorded. To overcome the adversity of seasons during June-September, short-term cold preservation technique was investigated to design the preservation schedule. Cocoons, adults and eggs were preserved at different temperatures (5^0C – 10^0C for cocoon and adult and 4^0C – 10^0C for eggs) for varied days (18 days for cocoon 7 days for adult and 21 days for egg). Eggs were collected after 24 hrs., 48 hrs., 72 hrs. and 96 hrs. of incubation. Finally, continuous preservation of cocoon, moth and eggs was studied to formulate a schedule of cold preservation to overcome the adversity of the aforementioned period.

1. Influences of environmental factors had strong reflection on fecundity and hatchability. During October – November the potential fecundity (276.60), realised fecundity (274.70) and upto 3rd days realised fecundity (217.80) were highest among the treatments which followed the performance during April – May (potential fecundity 248.20, realised fecundity 244.80 and upto 3rd days realised fecundity 200.70). During November – December and February – March the performance of egg laying in terms of potential fecundity (242.60 and 231.50 respectively), realised fecundity (238.70 and 228.00 respectively) and upto 3rd days realised fecundity (188.30 and 192.50

respectively) were better. However, October – November and November – December were the main commercial crop rearing season where silk production was the prime objective. During August – September, the seed production season for the supply of seed during those main commercial crop-rearing seasons, the egg laying performance was below the above mentioned periods (potential fecundity 227.90, realised fecundity 216.30 and upto 3rd days realised fecundity 169.70 respectively). The low potential fecundity during August – September was due to high temperature and humidity and the less realized fecundity was due to highly significant egg retention (11.60).

The correlation studies of these observations confirmed that temperature was the prime influencing extrinsic factor regarding fecundity (-0.99) and light period regarding hatchability (-0.99). Increase in temperature decreased the fecundity during August – September while increasing light period decreased the hatching percentage during August – September as well as during April – May.

Som plant showed bett er performance over soalu plant for both the intrinsic factors and grainage parameters during all the seasons, still failed to improve the grainage performance during April – May and August – September.

As the conventional seed crop production seasons *i.e.* August – September and April – May were low productive, utilization of February – March as a seed crop-rearing season instead of April – May and October – November as seed crop rearing season instead August – September might be done for better commercial crop rearing.

This slight modification of rearing schedule of Assamese calendar was found suitable for terai region of West Bengal having micro climatic variation with Assam. Further more, to maintain the rearing schedule of Assam (if the modification is not possible), manipulation of environmental factors for seed production or utilization of cold preservation technology were investigated.

During two seed crop rearing seasons, namely April - May and August - September 70% eggs were collected from 3 days laying. which were 205 and 181 eggs respectively of which only 89 and 111 eggs were hatched respectively. Upon collection of total laying of only 104.00 and 130.00 hatched larva were obtained during April – May and August – September respectively which were far lower than the collection of first 3 days during October – November (232.00) and February – March (193.00) to supply seed for commercial rearing. Moreover, this ultimately reflected in rearing hazards showing uneven rearing length and longer cocoon harvesting period as well as poor crop yield.

So, for supply of quality seed during commercial rearing collection of eggs from first three days was found effective for successful economic and synchronous rearing and it was further suggested that February – March and October - November found suitable as seed crop rearing period to have enough number of seeds during commercial rearing during March – April and November – December instead of May – June and October – November, which ultimately strengthened the suggestions made after observing seasonal influence on muga silkworm rearing and grainage operation.

2. Manipulation of temperature from 15^0C to 35^0C reflected that during April – May where normal temperature was 26.65^0C, manipulation of temperature to 25^0C increased the hatchability from 44.79% to 59.03% and during August – September when the normal temperature was 28.92^0C, manipulation of temperature to 25^0C increased the hatchability from 63.03% to 68.67%.

Relative humidity from 65% to above 90% manipulation showed that during April - May when normal RH was 68%, manipulation of RH to 75% increased the hatchability from 44.79% to 48.21% and during August – September when the normal RH is 77.5%, manipulation of RH to 75% could only level the normal hatching percentage while others failed.

Combined effect of temperature and RH manipulation showed a significant improvement of hatching percentage over control as well as over individual effect of temperature and RH during both the seasons. During April – May, when 44.79% was the normal hatching percentage and 25^0C temperature individually improved it up to 59.03% as well as 75% RH improved up to 48.21%, the combined effect of temperature and RH increased it up to 73.33% where the temperature and RH were 25^0C and 75% respectively. During August – September also, the combined effect of temperature and humidity improved the hatching percentage from 63.03% in normal condition or 68.67% at 25^0C temperature to 85% where the manipulated temperature and RH are 25^0C and 75% respectively.

Photoperiod influenced the uniform and perfect hatching; eggs should be incubated under proper light regimes for better hatchability. During April – May, where combined effect of temperature and humidity influenced the hatching percentage from 44.79% to 73.33%, 18 hour light improved it with a highest of 81.07%. During August – September also, photoperiod of 18 hour improved the hatching percentage from 85% to 92.97% where the manipulated temperature, RH and photoperiods were 25^0C, 75% and 18L. 25^0C temperature along with 85% RH at 18L.

Manipulation of 25^0C temperature with 75% RH and 18 hours light regimes improved the hatching percentage to a great extent and in the present findings adding the photoperiod at 18L condition (with 25^0C temperature and 75% RH) 93% hatching was achieved in contrast to 63% hatching in normal condition during August – September and 81.07% hatching can be achieved in contrast to 44.79% hatching in normal condition during April – May.

3. Earlier emergence of male moth has been proved principal constraint for egg production because asynchronous male and female moth emergence decreased coupling efficacy.

In the present investigation, the coupling efficacy of freshly emerged male and female was always better than any other combination. However, up to three days old male were coupled with fresh female showing good coupling efficacy. Fecundity and hatchability decrease after two days combination.

Coupling efficacy was improved from 71.27% to 90.60% in March – April and from 46.40% to 65.54% in September - October as a whole by short-term preservation at 10 ± 1^0C. One day preserved female showed higher coupling efficacy, fecundity and hatchability than fresh coupling. Moreover, the coupling efficacy of 3 days preserved female were also above 80%. Fecundity also increased after preservation, however, distinctive variation in hatching percentage was not so pronounced. It has been also observed that when preserved females took more crucial role than male.

Another way to overcome the constraint of asynchronous moth emergence reflecting less number of seed production was the repeated mating by exploiting the same male. For this, the optimum hours of mating should be recorded. So, in the first experiment, effect of different mating hours on egg laying and hatching were recorded. Non-significant results obtained from mating hours reflected that upto 12 hours mating any duration from second hour was sufficient for successful fertilization and egg laying. Minimum mating hours could be exploited and decoupled male could be utilized for repeated mating. However, in practice mechanical injury might damage both the male and fertilized female during decoupling within 5 hours. In the next experiment, repeated mating was conducted exploiting the males for a maximum of four times during March-April and of 6 time during September - October. During both the seasons though potential fecundity of the female were nearly same, repeated mating changed the egg laying and hatching. March-April showed that utilization of male upto 3 times had no harmful effect on fecundity as well as hatchability. During September-October utilization of male upto 4th time was effective in terms of egg laying and hatching.

So, in mugaculture, as synchronization of male and female was found one of the principal constraints of egg production, repeated exploitation of male moth upto four times prior to main commercial crop rearing season and upto three times before second commercial rearing by artificial coupling for seven hours to supply higher number of quality eggs to the farmers, was found effective.

4. To perform the seed cocoon screening, one of the estimators should be selected, if possible, for the farmer's point of view. Based on the regression equations obtained estimated value of fecundity, hatchability and egg vigour were worked out and deviation from the mean observed fecundity, hatchability and egg vigour showed that all the estimated grainage parameters based on the weight of the cocoon was the nearest estimated values to the observed value by the least deviation. Hence, weight of the cocoon was considered as the best estimator even though the other parameters also gave the near estimates of the observed fecundity, hatchability and egg vigour. Moreover, female cocoon weight was more determining factor than male and the combinations of high weight groups (male and female) performed better.

It was inferred that proper care should be taken while segregating the 20.11 percent population of male and female seed cocoons where male and female seed cocoons both overlapped each other between low, medium and high groups, in other groups the chances of error was negligible.

Keeping this view under consideration seven groups of female seed cocoon were selected on the weight basis namely extreme low (T_1 : 4.50 - 4.99 g), lower (T_2 : 5.00 - 5.49 g), low (T_3 : 5.50 - 5.99 g), moderate (T_4 : 6.00 - 6.49 g), high (T_5 : 6.50 - 6.99 g), higher (T_6 : 7.00 -7.49 g) and extreme high (T_7 : 7.50 - 7.99 g). It was observed that non-significantly best performing groups were extreme high, higher and high, meaning that female cocoons weighing above 6.50 g should be selected for seed production. Non-availability of these cocoons, moderate and low cocoon groups *i.e.* female cocoons weighing in between 5.50 g and 6.49 g could be selected for quality seed production.

5. Conventional main commercial rearing seasons (October – November) suffered badly due to poor supply of quality seed. Because the seed crop rearing failed (August – September) due to poor seed supply from pre seed crop rearing (June – July).

From the standpoint of more number of hatched larvae, 10^0C temperature was optimum for short-term preservation of cocoon as the emergence percentage and coupling efficacies are high. One day cold preservation of adult at 5^0C, 7^0C and 10^0C showed significantly better fecundity and hatchability than control. But the coupling efficacy of the adult was significantly lower when refrigerated at 5^0C and 7^0C than refrigeration at 10^0C which ultimately reflected in lower number of hatched larvae. So, from the standpoint of higher number of hatched larva, 10^0C temperature should be used for preservation of adult. Low temperature stress on eggs was exploited to control hatching period as and when needed. 24 hours old egg at 10^0C preserved for 21 days delayed hatching of 19 days having no deleterious effect on hatching percentage.

Keeping the results obtained from present experiment under consideration, the attempt was made to avoid rearing during June to August reflecting poor supply of seed during main commercial season (October – November) by refrigerating the cocoon from previous commercial crop (May – June), the subsequent adult and the eggs laid by them at 10^0C.

15 days cocoon preservation from preceeding commercial crop rearing delayed the moth emergence for 10 days, subsequent adult moth preservation for 5 days showed almost no deleterious effect on fecundity and hatchability. The eggs thus obtained preserved after 24 hours for 21 days delayed the hatching for 24 days. The eggs thus brushed were reared for supply of seed for commercial rearing. The grainage performance was also observed satisfactory.

So, by maintaining the schedule and preservation package collecting the cocoons from commercial crop of May – June, the adverse seasons were found to be avoided as well as only 35 paisa/dfl. additional expenditure was required to supply adequate amount of healthy seed to the farmers for main commercial crop rearing during October – November.

CHAPTER - VII

REFERENCES

Akai, H. (2005). The potential for Non-mulberry silks (wild silks). Proceedings of 20th International congress on wild silkmoth, Bangalore, Vol.- II, **Pp.** 6-7.

Ali, S. (1982). Effect of temperature on the hatching of eggs of Bombay locust, *Patanga succina* L. (Orthoptera : Acrididae). *Comp. Physiol. Ecol.*, **7(2):** 78-80.

Andrewarthe, H.G. and Birchi, L.C. (1954). The distribution of Animals, 1st Edition, *The University of Chicago press*, U.S.A.

Ayuzawa, C.; Sekido, I.; Yamakawa, K.; Sakurai, U.; Kurata, W.; Yaginuma, Y. and Tokoro, Y. (1972). Hand Book of Silkworm Rearing. *Fuzi Publishing Company*, Tokyo, Japan.

Babulal,; Khatri, R.K.; Siddiqui, A.A.; Sharma, A.K. and Saraswat, S.B. (2007). Sericulture in North India – Constraints and Strategies for Development. *Proceedings* of 20th Int. Cong. on Wild Silk Moth. Delhi, Vol – III, Pp- 176.

Badhera, S. (1992). Relationship between pupal dimensions and fecundity in tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera : Saturniidae). *Uttar Pradesh J. Zool.*, **12(1):** 37-39.

Balinsky, B.I. (1981). An Introduction to Embryology – Saunders College, Philadelphia.

Barah, A. and Sahu, A.K. (2003). Utilization of Male moths of muga silkworm, *Antheraea assama* Ww. (Lepidoptera: Saturniidae) for multipul coupling. *Bull. Ind. Acad. Seri.* **7(1)**: 94-98.

Barah, A.; Sengupta, A.K. and Samson, M.V. (1993). Effect of temperature and humidity on hatching of eggs of the muga silkworm, *Antheraea assama* Ww., during incubation. *Sericologia,* **33(2):** 343-347.

Bardoloi, S. and Hazarika, L.K. (1994). Body temperature and thermoregulations of *Antheraea assama* larvae. *Entomol. Exp. Appl.*, **72:** 207 – 217.

Beck, S.D. (1980). Insect photoperiodism. *Academic press*, New York, **Pp.** 156-160.

Benchamin, K.V. and Giridhar, K. (2005). Sericulture Industry in India. *Proceedings of 20th International congress on wild silkmoth*, Bangalore, Vol – III, **Pp.** 158-161.

Benchamin, K.V. and Jolly, M.S. (1986). The principle of silkworms rearing. *Proceeding* of the Seminar on Prospectus and Problem of Sericulture in India (Mahalingngam, S, Ed.). **Pp.** 63-168.

Benchamin, K.V.; Gapuz, V. and Jayaramaraju, P. (1990). Influence of photoperiod on emergence, fecundity and fertility in multivoltine breeds of silkworm, *Bombyx mori* L. *Indian J.* Seri., **29:** 110-118.

Benchamin, K.V.; Magadum, S.B. and Shivashankar, N. (1990). Mating capacity of male moths of pure breeds and hybrids in silkworm *Bombyx mori* L. *Indian J. Seric.*, **29(2):** 182-187.

Bindroo, B.B. and Khan, M.A. (2007). Autumn Crop Productivity in CSB Adopted Areas. *Indian Silk*, **45(10):** 9-10.

Biren Rana; Lukham R.; Chalapathy, M.V.; debraj, Y; Ibohal Singh, N.; Sinha, R.K. and Thangavelu, K. (2002). Effect of refrigeration on the hatchability of different ages of oak tasar silkworm eggs, *Sericologia*, **42(2)**: 581-584.

Biswas, I. and Ray, N. (2003). Exploitation of muga culture in terai region of West Bengal, a non-traditional area. *Proc. of 4^{th} all India people's technology Congress.* February 23-24, Kolkata. **Pp.** 86-90.

Biswas, I. and Ray, N. (2007). Studies on short term cold preservation for supply of seed during main commercial crop rearing of muga silkworm. *J. Exp. Zool.*, India. 10(2): 271-276.

Bora, D. (1998). Effect of environmental stress with special reference to photoperiod and insecticide on muga worms, *A. assama* Ww. Ph. D Thesis, Dibrugarh University, Assam.

Boswell, R.E. and Mahowald, A.P. (1985). Cytoplasmic determinants in embryogenesis. In Comprehensive Insect Physiology, Biochemistry and Pharmacology, Eds. Kerkut, G.A. and Gilbert, L. I., Vol. I., *Pergamon Press*, Oxford. **Pp.** 387-405.

Chaturvedi, M.L. and Upadhyay, V.B. (1990). Effect of cold storage in the hatchability of silkworm (*B. mori*) eggs. *J. Adv. Zool.*, **11(1):** 63-65.

Chaudhuri, C.C.; Dubey, O.P.; Chaudhuri, A. and Sengupta, K. (1987). Effect of refrigeration on the preservation of muga cocoons, *Antheraea assamensis,* XVth International Sericultural Congress, Thailand. **Pp.** 122-127.

Choudhuri, C.C. (2003). Studies on periodical variations in some economic characters of muga silkworm, Antheraea assama, on som, Machilus bombycina and Soalu, Litseae polyantha. Abstract of National Conference on Tropical Sericulture for global competitiveness, CSTRI, Mysore, India. **P** 121.

Chowdhury, S.N. (1984). Mulberry silk industry, (1st Edn.). Shillong, **P.** 83.

Clark, A.M. and Rockstein, M. (1964). Aging in insects. In The Physiology of Insecta, M. Rockstein (Ed.), Vol. 1, 1st Ed., **Pp.** 277-281.

Crotch, W.J.B.A. (1956). Silk moth rearers' handbook. The Ameture Entomologists' Society. **12:** 55-130.

Danilevski, A.S. (1965). Photoperiodism and seasonal development of insects. (I Edn.). Oliver and Boyd (Eds.). Edinburgh, **P.** 51.

Das, B.K.; Sarkar, J.; Das, C. Das, N.K. and Sen, S.K. (1995). Seasonal effects on the relative performance of five bivoltine breeds of silkworm Bombyx mori L. in Malda. *Uttar Pradesh J. Zool.*, **52(2):** 91-96.

Datta, R.K.; Sengupta, K and Biswas, S.N. (1972). Studies on the preservation of multivoltine silkworm eggs at low temperatures, *Indian J. Seric.*, **11(1)**: 20-26.

Datta, R.K.; Sengupta, K. and Biswas, S.N. (1972). Studies on the refrigeration of multivoltine silkworm eggs at low temperatures, *Indian J. Seric.*, **11:** 20-27.

Dubey, O.P.; Singh, B.M.K. and Suryanarayana, N. (2005). Selection of seed cocoons in *Antheraea mylitta* drury (daba BV) and its correlation with fecundity and hatching. *Proceedings of 20th International congress on wild silkmoth*, Bangalore, Vol. II Pp. 53-57.

Engelmann, F. (1970). The Physiology of Insect Reproduction. *Pergamon Press*, Oxford. New York.

Francis, C.R.; Kumaresan, P. and Benchamin, K.V. (1995). Application of linear programming technique to plan optimum production of laying in a commercial grainage. *Indian J. Seric.*, **34(1):** 28-33.

Ghosh, B.; Chattopadhayay, S.; Rao, P.R.T.; Das, S.K.; Roy, G.C.; Sen, S.K. and Sinha, S.S. (1993). Analysis of Quantitative traits of multivoltine silkworm, B*ombyx mori* L. (Lepidoptera: Bombycidae) in varied environments, *Uttar Pradesh J. Zool.*, **13(1)**: 47-51.

Ghosh, M.K.; Roychowdhuri, S.; Shiv Nath, S.; Ghosh, P.K. and Sankar, A. (2007). Development of Mulberry varieties for Eastern India. *Indian silk*, **46(3):** 4-6.

Govindan, R.; Devaiah, C.; Rangaswamy, H.R. and Thippeswamy, C. (1980). Effect of refrigeration of the eggs of Eri silkworm, *Samia cynthia ricini* Boisduval on hatching. *Indian J. Seric.*, **19:** 13-15.

Gowda, B.L.V.; Sannaveerappannvar, V.T. and Shivayogeshar, (1998). Fecundity and hatchability in mulberry silkworm, *Bombyx mori* L. as influenced by pupal weight. *Proceedings of the International Congress on Tropical Sericulture Practices.* February, 18-23, **Pp.** 21-23.

Gowda, P., (1988). Studies on some aspects of egg production in silkworm, *Bombyx mori* L. Ph. D. Thesis, Mysore University, Mysore, India.

Hazarika, L.K.; Kataky, A.; Katky, J.C.S. and Hazarika, J. (1995). Fats and faty acids composition of muga silkworm and its host plants. *J. Assam. Sci. Soc.*, **37(1):** 45-50.

Howe, R.H. (1967). The temperature effects on embryonic development in insects, **12** : 15-42. In "Annual Review of Entomology" Ed. Smith, R.F. & Mittler, E; *Annual Review* INC, U.S.A.

Ibohal Singh, N.; Ibotombi Singh, L.; Somen Singh, L. and Suryanarayana, N. (2005). An overview of the salient features of Antheraea frithii Moore – A promising wild silkmoth of India. Proceedings of 20th International congress on wild silkmoth, Bangalore, Vol.- II, Pp. 74-77.

Ito, T. and Arai, N. (1965). Nutrition of the silkworm *Bombyx mori* III. Amino acid requirements and nutritive effects of various proteins. *Bull Seric Exp Sta.*, 19 : 370-372.

Janarthanan, S.; Sathiamoorthi, M.; Subburathenam, L.M. and Krishnan, M. (1994). Photoperiod : Its effects on larval pupal character, fat body, nucleic acids and protein of silkworm, *Bombyx mori* L. *Insect Sci. Application*, **15:** 129-137.

Jolly, M.S. (1983). Organization of bivoltine grainage for tropics. Sericulture project 3. CSRTI, Mysore.

Jura, C. (1972). Development of apterygote insects. In Development Systems – Insects, eds. Counce, S.J. and Waddington, C.H., Vol. I. *Academic Press*, London and New York, **Pp.** 49-94.

Kar, J.K. and Guru, B.C. (1998). Influence of season on the life span and commercial traits of cultivated eri silkmoth *Samia ricini* Donovan. *The 3rd International Conference on Wild Silkwmoth*, Bhubaneshwar, Orissa, November, 11-14.

Khanikor, D.P. and Dutta, S.K. (1998). Low temperature of seed cocoons for delaying moth emergence in muga silkworm (*Antheraea assama* Westwood) (Lepidoptera : Saturniidae). The *3rd International Conference on Wild Silk moths.* Bhubaneswar, Orissa. November 11-14.

Khatri, R.K.; Babulal,; Sharma, A.K and Sharma, K.K. (2007). Oak tasar culture in India : some issues. *Indian Silk*, **45(10):** 19 –21.

Kogure, M. (1933). The influence of light and temperature on certain characters of silkworm, *Bombyx mori. J. Dep. Agric., Kyushu University.*, **4:** 1-93.

Kotikal, Y.K.; Reddy, D.N.R.; Prabhu, A.S.; Bhat, G. G. and Pushpalatha, S. (1989). Relationship between pupal size and egg production in eri silkworm, *Samia Cynthia ricini* (Lepidoptera : Saturnidae). *Indian J. Seric.,* **28(1):** 80-82.

Li, R. and Samo, Q. (1984). The relationship between quality of mulberry leaves and some economic characters during the later larval stages. *Sci. Seric.* (*Canye Kexue*), **10:** 197-201.

Mahanta, H.C. and Goswami, M.C. (1986). Some aspects of influence of photoperiod on muga silkworm, *Antheraea assama* Westwood (Lepidoptera : Saturniidae). *Uttar Pradesh J. Zoology.*, **6(1):** 98 – 107.

Masaki, S. (1972). Climatic adaptation and photoperiodic response in the band-legged ground cricket. *Evolution,* **26:** 587-600.

Mathur, S.K.; Singhvi, N.R. and Kushwaha, R.V. (2005). Effect of prolonged high temperature and long humidity on fertility and fecundity in tropical tasar silkworm. *Indian Silk*, **43(12):** 18-19.

Mathur, V.B.; Singh, G.P.; Ghosh, P.K. and Datta, R.K. (2003). Effect of high temperature on early instar of the silkworm *Bombyx mori* L. *Bull. Ind. Acad. Seri.*, **7(1):** 48-54.

Matsumara, (1975). In : Tropical Sericulture (ed. Yokoyama), *Overseas Cooperation Volunteer*, Tokyo, Japan., **Pp.** 444-537.

Maurya, K.R. and Mishra, P.N. (1993) Effect of Complin Duration on fecundity and Hatchability of *Antheraea proylei* J. Eggs *Indian silk*, **32(3)**: 49-50

Meenal, A; Mathur, V.B. and Ranjan, R.K. (1994). Role of light during incubation of silkworm eggs and its effect on rearing performance and diapause. *Indian J. Seric.*, **33(2):** 139 - 141.

Millar, A.T.; Cooper, W.J. and Highfill, J.W. (1982). Relationship between pupal size and egg production in reared female *Antheraea polyphemus*. *Ann. Entomol. Soc. Am.*, **75** : 107-108.

Mohan Rao, K. (2007). Tasar Culture and forest Policy-Constraints and guidelines. *Indian silk,* **45(10):** 14-18.

Nagalakshmamma, K. (1987). Investigation on some aspect of seed technology in Eri silkworm, *Samia Cynthia ricini*. Biosduval. *M.Sc.* (*Agril.*) *Thesis*, Univ. of Agril. Science, Bangalore. **Pp.** 84.

Nakada, T. (1932). The resistance of silkworm embryo to abnormal high temperature and dryness on the external morphology of the embryo. *Bull. Fukuoka Sericult. Expt. Stn.*, **1:** 1-26.

Nangia, N. and Nagesh Chandra, B.K. (1988). On the effect of low temperature on egg hatch & subsequent development of *Samia Cynthia ricini* Biosduval (Lep. : Sat.). *Sericologia*, **28(3):** 337-341.

Narasimhanna, M.N. (1986). *Indian J. Seric.*, **3:** 13-16.

Nirmal Kumar, S.; Sashindram,; Nair, K. and Jagat Rabha. (2005). Interaction of ambient temperature and time of treatment of phytoecdysteroid in the larval malnutrition process and crop performance of bivoltine hybrid (CSR 2 X CSR4) silkworm, *Bombyx mori* L. *Indian J. Seric.*, **44**(1):118-124.

Ochieng-Odero, J.P.R. (1992). The effect of three constant temperatures on larval critical weight, latent feeding period, larval maximal weight and Fecundity on *Cnephasis jactatana* (Walker) (Lepidoptera : Tortricidae). *J. Insect Physiol.*, **38(2):** 127-130.

Ojha, N.G.; Sharan, S.K.; Ravikumar, G.; Dubey, O.P.; Sinha, B.R.R.P. and Sinha, S.S. (1996). Effect of refrigeration on mating efficiency of male moths of Tasar silkworm, *Antheraea mylitta* D. *Indian J. Seric.*, **35(2):** 155-157.

Pandry, R.K.; Luikham, R.; Das, P.K. and Noamani, M.K.R. (1992). Effect of cold storage on the hatchability of oak tasar silkworm. *Indian Silk,* **31(2):** 45-46.

Raja Ram and Samson, M.V. (1998). Effect of Different types of diet of Dighloti, Majankuri, Som and Soalu leaves on the rearing on Muga Silkworm, *Antheraea assama* Westwood. *The 3rd International Conference on Wild Silkwmoth,* Bhubaneshwar, Orrisa, November, 11-14.

Raja Ram; Kumar, S.; Roy, G.C.; Sinha, A.K. and Sinha, B.R.R.P. (1998). Effect of different morphot ypes of *Quercus sem ecarpifolia* on the rearing of *Antheraea proylei* J. *The 3rd International Conference on Wild Silkwmoth,* Bhubaneshwar, Orrisa, November, 11-14.

Rath, S.S. (1998). Studies on growth and development of *Antheraea mylitta* Drury, (Lepidoptera: Saturniidae) fed on three different natural host plats. . *The 3rd International Conference on Wild Silkwmoth,* Bhubaneshwar, Orrisa, November, 11-14.

Rath, S.S. (1998). Survival probability and fertility in male moths of *Antheraea mylitta* Drury, (Lipidoptera: Satrurniidae) during aging. *The 3rd International Conference on Wild Silkwmoth*, Bhubaneshwar, Orrisa, November, 11-14.

Ray, N. (2003). Muga steps in West Bengal. Recent Advances in Animal Science Research., *Orion Press International*, India. **2:** 284-288.

Ray, N.; Bhattacharya, A.; Senapati, S.K. and Deb, D.C. (1998). Selection of mulberry (*Morus* sp) varieties based on yield, nutritional elements and its bearing upon bivoltine silkworm (*Bombyx mori* L) for terai region. *Environmental and Ecology*, **16(1):** 91-94.

Ray, N.; Biswas, I.; Bhattacharya, U.; Das, S.K. and Das, P.K. (2005). Studies on rearing performance of muga silkworm (*Antheraea assama*) in terai region of West Bengal (India) a newly explored area. *Indian J. Seric.*, **44(1):** 107-112.

Rockstein, M. (1974). The insect and external environment. In : The physiology insects – Vol. II, *Academic Press*, New York.

Saha, A.K.; Pal, N.B.; Ghosh, S.; Pandit, D.; Das, S.K. and Sarkar, A. (2007). Field level Evaluation of Productive hybrid NXYB. *Indian Silk*, **45(10):** 11-12.

Sahu, A. K. (2004). Muga silkworm seed production : Constraints and strategies. *Indian silk*, **42(2):** 14-17.

Sahu, A.K.; Singha, B.B. and Das, P.K. (1998). Phenological studies in muga silkworm, Antheraea assama Ww. (Lepidoptera : Saturniidae), in relation to its rearing and grainage behavior. Proc. of *The 3rd International Conference on Wild Silkwmoth*, Bhubaneshwar, Orrisa, November, 11-14. **Pp.** 25-31.

Sahu, M; Mukherjee, P.K. and Mondal, T (1998). Constraints during pre-seed crop rearings of *Antheraea assama* Ww. At seed rearers level in lower Assam. *The 3rd International Conference on Wild Silkwmoth*, Bhubaneshwar, Orrisa, November, 11-14.

Sakate, S.; Kato, Y.; Suzuki, K. (1982). Effects of photoperiod and temperature on termination of summer diapause in pupae of *Antheraea yamamai*. *J. Seric. Sci. Jpn.*, **51:** 1-4.

Salt, R.W. (1961). Principles of cold hardiness. *Annu. Rev. Ent.*, **6:** 55-74.

Samachary, S.M.V. and Krishnaswami, S. (1980). Some useful correlation studies of silkworm and its products such as cocoon, pupa, shell and egg weight. *Indian J. Seric.*, **19(1):** 4-8.

Samson, M.V. and Barah, A. (1989). Suggestions for better Muga Seed Production. *Indian Silk*, June-1989, 15-16

Sander, K.; Gutzeith, H.O. and Jackle, H. (1985). Insect embryogenesis : Morphology, Physiology and Molecular aspects. In : Comprehensive Insect Physiology, Biochemistry and Pharmacology, eds. Kerkut, G.A. and Gilbert, L.I. Vol. I., *Pergamon Press*, Oxford. **Pp.** 321-385.

Saunders, D.S. (1982). Insect clocks. *Pergamon Press*, Oxford.

Sengupta, K. and Singh, K. (1974). Some studies on the effect of refrigeration of muga Antheraea assama Ww. cocoons on moth emergence, egg laying and hatching of eggs. First International Seminar on Non-mulberry silks, CTR & TI, Ranchi, 174.

Shaheen, A.; Trag, A.R.; Nabi, G.H. and Ahmad, F. (1992). Correlation between female pupal weight and fecundity in bivoltine silkworm, *Bombyx mori* L. *Entomon*, **17(1&2):** 109-111.

Siddiqui, A.A. and Das, P.K. (1998). Genetic variation and correlation studies for technological traits in *Antheraea assama* Westwood: endemic species of North East India. *The 3rd International Conference on Wild Silkwmoth*, Bhubaneshwar, Orrisa, November, 11-14.

Sidhu, N.S. (1967). A multivoltine breed of Silkworm, *Bombyx mori* L. for tropics in evolution. *Ind. J. Seric.*, **6:** 63-66.

Singh, N.I. (1992). Studies on the effect of preservation of female moths on egg laying and rearing of silkworm, *Bombyx mori* L. *Dissertation* submitted to I.C.T.R.E.T.S., Mysore.

Singh, R.; Chaturvedi, H.K. and Datta, R.K. (1994). Fecundity of mulberry silkworm, *Bombyx mori* L. in relation to female cocoon weight and repeated matings. *Indian J. Seric.*, **33(1)**: 70-71

Singha, B.B.; Lepcha, S.T. and Paramanik, A.T. (1991) Muga finds its way to West Bengal. *Indian Silk*, **30(5)**: 41-43.

Singha, B.B.; Sahu, A.K. and Das P.K. (1998). Identification of low temperature resistant embryonic stage(s) in muga silkworm, *Antheraea assama* Ww. *The 3rd International Conference on Wild Silkwmoth,* Bhubaneshwar, Orrisa, November, 11-14.

Singha, U.S.P.; Bajpeyi, C.M.; Sinha, A.K.; Barhmachari, B.N. and Sinha, B.R.R.P. (1998). Food consumption and utilization and utilization in *Antheraea mylitta* Drury larvae. *The 3rd International Conference on Wild Silkwmoth,* Bhubaneshwar, Orrisa, November, 11-14.

Sivaram Reddy, N. and Sasira Babu, K. (1990). Hatching patterns in the silkworm *Bombyx mori* L. (PM x NB4D2) under different photoperiodic combinations. *Proc. Indian Acad. Sci., (Anim. Sci.)*., **99:** 327-334.

Sonobe, H.; Maotaini, K. and Nakajima, H. (1986). Studies on embryonic diapause in the PND mutunat of the silkworm, *Bombyx mori.* – Genetic control of embryogenesis. *J. Insect Physiol.*, **32:** 215-220.

Soo Hoo, C.F. and Fraenkel, G. (1966). The selection of food plants in a polyphagous insect, *Prodenia eridania* (Gamer). *J. Insect M.A. Physiol.*, **12:** 693-709.

Srivastava, A.K.; Nagri, A.H.; Roy, G.C.; and Sinha, B.R.R.P. (1998). Temporal variation in qualitative and quantitative characters of *Antheraea maulitta* Drury. *The 3rd International Conference on Wild Silkwmoth,* Bhubaneshwar, Orrisa, November, 11-14.

Subramanyam, K. (1982). Studies on the effect of rest on the efficiency of male moths in relation to number of mating and occurrence of viable eggs in silkworm *B. mori.* L. STS dissertation submitted ICTRETS, C.S.R & T.I, Mysore, 14-15.

Takami, T. (1969). A General Text Book of the Silkworm Egg. *Zenkoku Sanshu Kyokai,* Tokyo, Japan.

Takami, T. and Kitazawa, T. (1960). Eternal observation of embryonic development in the silkworm. Sanshi Shikenjo, Kokoku, Sericult. Expt. Stn. *Tech. Bull.,* **75:** 1-31.

Tanaka, Y. (1964). *Sericology.* Central Silk Board. **Pp.** 83-98.

Tazima, Y. (1978). 'Silkworm Egg' – Published by Central Silk Board, India.

Thangavelu, K. and Sahu, A.K. (1985). Further studies on the indoor rearing of muga silkworm (*Antheraea assama* Ww.) (Saturnidae : Lepidoptera) *Sericologia,* **26(2):** 215-224.

Thangavelu, K.; Chakraborty, A.K.; Bhagowati, A.K. and Isa, Md. (1988). Handbook of muga culture, Central Silk Board, Bangalore.

Toyama, K. (1902). Contribution to the study of silkworm. I. On the embryology of the silkworm. *Bull. Coll. Agric.* Tokyo, Imp. Univ., **5:** 73-118.

Turumaki, J.; Ishiguro, J.; Yamanaka, A. and Endo, K. (1999). Effect of photoperiod and temperature on seasonal morph development and diapauses egg oviposition in a bivoltinr race (Daizo) of the silk moth, *Bombyx mori* L. *Journal of Insect Physiology.*, 45: 101-106.

Unni B.G.; Katory, A.K.; Khanikard, D.; Bhattacharjee, P.R.; Phatak, M.G.; Pallai, K.; Pillai, R.; Choudhury, A.; Saikia, P.C. and Ghosh, A.C. (1996). Lipid and fatty acid composition of muga silkworm, *Antheraea assama,* host plants in relation to silkworm growth. *J. Lipid Med. Cell Sig.,* **13:** 295-300.

Upadhaya, V.B. and Pandey, A.K. (2000). Effect of refrigeration on eggs and prerefrigeration period on the survival of larvae of *Bombyx mori. Indian J. Ent.*, **62 (1)**: 28-33

Upadhyay and Gaur K.P. (2002). Effect of ecological factors on the incubation period of *Bombyx mori* eggs. *Indian J. Ent.*, **64(3)**: 368-372.

Venugopala Pillai, S. and Jolly, M.S. (1985). An evaluation on a quality of mulberry varieties under hill conditions and crop result of *Bombyx mori* L. *Indian. J. Seric.* **24:** 48-52.

Vishwakarma, S.R. (1982-83). Effect of refrigeration of Eri silkworm, *Philosamia ricini* Hutt eggs on the hatching (Lep. Sat.). *Indian J. Seric.*, 36-39.

Walters, F.L. (1967). Effect of temperature on hatching & development of *Tribolium confusum. J. Stored Products.* Referred to in Howe, R.H., *Annual Review of Entomology*, **12:** 15-42.

Wigglesworth, V.B. (1972). The principles of insect physiology. *Methuen & Co.*, London.

Yadav, G.S. and Goswami, B.C. (1986). Golden muga silk in Mizoram, *Indian silk*, **25:** 15-16.

Yaginuma, T.; Kobayashi, M. and Yamashita, O. (1990). Effects of low temperatures on NAD-sorbitol dehydrogebease activity and morphogenesis in non-diapause eggs of the silkworm, *Bombyx mori. Comp. Biochem. Physiol.*, **97B(3):** 495-506.

Yamashita, O. and Yaginuma, T. (1991). Silkworm eggs at low temperatures : Implications for sericulture. In 'Insects at Low Temperature', eds. Lee, R.E. and Denlinger, D.L., *Chapman and Hall*, New York. **Pp.** 424-445.

Yamazaki, H. (1959). Present status of rearing of *A. yamamai* and *pernyi* and its future design. *Bull.* 25. Central Silk Board, Bombay.

Zhang Xianbo, Zhang Yanru, Zhang Xiuzhen and Meng Gang, (1998). On legal construction in the natural protective region of *Antheraea yamamai. The 3rd International Conference on Wild Silkwmoth,* Bhubaneshwar, Orrisa, November, 11-14.

Zhang, C.X.; Xu, J.L. and Wu, X.F. (1991). Effect of dietary protein level on the growth, development and reproduction of the silkworm, *Bombyx mori* L. Canye Kexue, **17** : 217-222.

PUBLICATIONS RELATED TO THIS WORK

Brief note

STUDIES ON SEED (EGG) PRODUCTION WITH REFERENCE TO MATING BEHAVIOUR OF MUGA SILKWORM, *ANTHERAEA ASSAMA* WESTWOOD*

INDRAJIT BISWAS & NILAY RAY

Muga Research Laboratory, A.B.N. Seal College, Cooch Behar - 736101- West Bengal, India

The experiment was conducted in Muga Research Laboratory, A.B.N. Seal College, Cooch Behar to overcome the constraints regarding seed (egg) production of Muga silkworm ***Antheraea assama*** *Ww. through manipulating their mating behaviour to standardize the mating hours and utilisation of male moth for more than one time for better supply of quality seed to farmers. Mating duration of 7 hours showed highest fecundity and hatching. Utilisation of male moth up to 3 times during March-April and up to 4 times during Sept.- Oct. had no harmful effect on fecundity as well as hatching. It could be suggested that 7 hours mating would be optimum and the same male moth could be utilised up to three / four times without any hampering effect on egg production and hatching for better supply of eggs to the farmers for muga culture.*

Keywords: Muga silkworm, egg laying, egg retention, hatching, repeated mating

INTRODUCTION

Muga Silkworm (*Antheraea assama* Ww.) is a highly heterogeneous, unique and semi-domesticated strain of Saturniidae endemic to Assam, adjacent foothills of Meghalaya, Nagaland, Arunachal Pradesh and Mizoram. Exploration of Muga culture in Terai region of West Bengal particularly in Cooch Behar and Jalpaiguri districts having contiguity with Assam faces problems related to supply of egg. Production of large number of eggs for farmers is a serious problem in Assam (Sahu *et al.,* 1998). Uneven sex-ratio, poor seed cocoon and its preservation and asynchronous moth emergence resulting in poor mating and poor number of egg production are the principal constraints other than environmental stresses (Samson and Barah, 1989). Though works related to male-female ratio and seed cocoon production through improvement of rearing technology are in progress (Annual Report, RMRS, CSB, Boko, Assam, 1997), efforts to overcome asynchronous moth emergence to ensure higher mating percentage leading to higher fecundity is very limited in muga silkworm and the approach is only to synchronise male and female through short-time preservation (Khanikor and Dutta, 1989). In mulberry silkworm (*Bombyx mori* L.), some works have been attempted by exploiting male moths for more than one time to overcome the sex ratio problem as well as asynchronous moth emergence (Benchamin *et al.,* 1990). In Tasar silkworm (*Antheraea militta*) repeated mating has been adopted as practice (Ojha *et al.,* 1996). In the present investigation, an attempt has been made to overcome the constraints in muga silkworm through manipulating their mating behaviour to standardize the mating hours and utilisation of male moth for more than one time for better supply of quality seed to the farmers.

* (Paper presented at 90^{th} Indian Science Congress, Bangalore, 3 – 7^{th} January, 2003.)

MATERIALS AND METHODS

Seed cocoons were collected from Extension Centre (Cooch Behar, West Bengal), Regional Muga Research Station, Central Silk Board and the experiment was conducted thrice during 2001-2002 in muga research laboratory, A.B.N. Seal College, Coot Bear. Eleven (11) treatments for standardisation of mating hours were selected from 2 hours to 12 hours with one hour interval, egg laying and retention were taken as quantity production parameters and hatching number and percentage were taken as quality production. Subsequently in another experiment males were exploited up to a maximum of 6 times during Sept.-Oct. and four times during March-April with fresh female and egg laying, retention and hatchability were taken as key parameters. All data collected were analysed statistically.

RESULTS

a. Effect of different mating hours on egg laying and hatching:

No significant differences were observed between different mating hours on egg laying, retention and hatching. However, highest fecundity was observed when mating was allowed for seven hours (287), lowest being from 12 hours (250). Egg retention was nearly nil to 11 hours. Number of egg hatched was highest from seven hours (284) which was 99.19%, lowest being from 12 hours which was 235 and 94% for egg laying and hatching respectively (Table I).

Table I. Data on egg laying and hatching as influenced by different mating hours.

Tableau I. Données sur la ponte et l'éclosion sous l'influence de différentes heures d'accouplement.

Mating Hours *Heures d'accouplement*	**Egg laying (no.)** *Ponte des œufs (nbre)*	**Egg Retention (no.)** *Rétention d'œufs (nbre)*	**Hatching (no.)** *Eclosion (nbre)*	**Hatching percentage (%)** *Pourcentage d'éclosion (%)*
2 hrs.	267	10	253	95
3 hrs.	269	9	265	99
4 hrs.	273	9	266	97
5 hrs.	280	6	277	99
6 hrs.	279	6	273	98
7 hrs.	287	2	285	99
8 hrs.	276	8	267	97
9 hrs.	273	5	266	97
10 hrs.	252	4	250	99
11 hrs.	251	3	247	98
12 hrs.	250	6	235	94
CD at 5%	Non-Significant *Non significatif*	Non-Significant *Non significatif*	Non-Significant *Non significatif*	Non-Significant *Non significatif*

Table II. Data on grainage performance as influenced by repeated mating during March-April.

Tableau II. Données sur la performance de grainage sous l'influence d'un accouplement répété en mars – avril.

Treatment ***Traitements***	**Egg laying (no.)** ***Ponte d'œufs (nbre)***	**Egg Retention (no.)** ***Rétention d'œufs (nbre)***	**Hatching (no.)** ***Eclosion (nbre)***
Fresh male × fresh female *Nouveau mâle × nouvelle femelle*	232	7	231
Single mated male × fresh female *Mâle accouplé une fois × nouvelle femelle*	207	7	197
Double mated male × fresh female *Mâle accouplé deux fois × nouvelle femelle*	194	15	164
Triple mated male × fresh female *Mâle accouplé trois fois × nouvelle femelle*	75	140	0
C.D. at 5% / *DC à 5 %*	**3**	**9**	**4**

b. Effect of number of matings utilising single male moth on egg laying and hatching:

Results obtained from repeated mating during March-April were depicted in Table II and that of during September-October in Table III.

During March-April:

During March-April, prior to second commercial crop rearing period i.e. April-May one male moth could be forced to couple with fresh female up to four times.

Egg laying:

Significant variations observed between the treatments. Highest egg laying was recorded when fresh male and female moths were coupled (232). A decreasing trend was observed from second time utilization to 4th time utilization of the same male moth. There observed significant variation in egg laying between second (207) and third time (194) exploitation of the same male moth. But significantly abrupt decreased egg laying was observed when extreme utilization of male moth for the fourth time was done (75).

Egg Retention:

Egg retention was not significantly higher inside the female body up to 3rd time utilization of a single male (7 to 15). But the egg retention in the female body when coupled with a male utilising for the 4th time was very high (140) which was even nearly double than the egg laid by that female.

Table III. Data on grainage performance as influenced by repeated mating during September-October.

Tableau III. Données sur la performance de grainage sous l'influence d'un accouplement répété en septembre – octobre.

Treatment ***Traitement***	**Egg laying (no.)** ***Ponte d'œufs (nbre)***	**Egg retention (no.)** ***Rétention d'œufs (nbre)***	**Hatching (no.)** ***Eclosion (nbre)***
Fresh male × fresh female *Nouveau mâle × nouvelle femelle*	264	6	262
Single mated male × fresh female *Mâle accouplé une fois × nouvelle femelle*	252	12	247
Double mated male × fresh female *Mâle accouplé deux fois × nouvelle femelle.*	254	7	249
Triple mated male × fresh female *Mâle accouplé trois fois × nouvelle femelle*	248	16	244
Tetra mated × fresh female *Accouplé quatre fois × nouvelle femelle*	237	25	198.
Penta mated male × fresh female *Mâle accouplé cinq fois × nouvelle femelle*	136	125	0
C.D. at 5% / *D. C. à 5 %*	**7**	**5**	**6**

Hatching:

Number of hatched egg was significantly highest (231) from the egg laid by the female coupled with fresh male. The number of hatched egg recorded was 197 and 164 from the egg laid by the females repeatedly utilization of males for 2nd and 3rd times, respectively. Most striking observation was that no egg was hatched when the female mated with the male utilising for the fourth time.

During September-October:

During September-October- prior to main commercial rearing i.e. October-November one male moth could be exploited up to 6th time to mate with the fresh females.

Egg laying:

Like March-April, during September-October also the egg laying was found significantly highest (264) when fresh female were coupled with fresh male. Eggs laid by the females mated with the males utilising for 2nd, 3rd and 4th time had non-significant variation among them (248– 254). Eggs laid by the females mated with the male exploited for the 5th time was significantly lower (237). But repeated utilization of the male moth for the 6th time with fresh female reflected very low egg laying (136).

Egg retention:

Egg retention was 6 to 16 inside the female body coupled with up to 4th time utilization of single male moth. Very huge amount of egg retention (125.00) was recorded inside the female body when mated with a male utilised earlier for the five times.

Egg hatching:

Significantly highest number of hatched eggs was observed by the eggs laid by the female when coupled with fresh male (262) followed significantly by the eggs laid by the female mated with the males for 2nd to 4th time (244–249). Number of hatched eggs decreased significantly in the eggs laid by the females mated by the male repeatedly used for the 5th time (199). Surprisingly no egg was hatched for the females when coupled with the male utilised for sixth time.

DISCUSSION

Success of muga culture highly depends upon seed (egg). Lack of supply of quality seeds (high hatching) not only affects commercial rearing but also disappoints farmers who are trying to adopt the muga culture in the newly adopted area of extended muga culture in terai region of West Bengal. The two main commercial crop-rearing seasons are October-November and April-May. Success of grainage during March-April and September-October is the foremost task to ensure the supply of large quantity of quality seed during commercial rearing. Asynchronous moth emergence and less number of seed cocoon productions are the principal constraints regarding egg production. Repeated mating by exploiting the same male can help to overcome this problem. For this, the optimum hours of mating should be recorded. Therefore, in the first experiment, effect of different mating hours on egg laying and hatching have been recorded (Table I). Non-significant results obtained from mating hours reflects that up to 12 hours mating any duration from second hour is sufficient for successful fertilization and egg laying which confirms the observations of Samson and Barah (1989), according to whom 3-5 hours mating is sufficient. From this observation it can be suggested that minimum mating hours can be exploited and the decoupled male can be utilized for repeated mating. However, in practice mechanical injury may damage both the male and fertilized female during decoupling within 5 hours. Moreover, mating duration of 7 hours shows highest fecundity and hatching, though the differences with others are not significant. Therefore, mating duration of 7hours can be suggested as optimum for successful mating, egg laying and hatching.

In the next experiment, repeated mating has been conducted exploiting the males for a maximum of four times during March-April (Table II) and of 6 times during September-October (Table III) because it has been reported that female fertility in silkworm depends upon their male mates (Sidhu *et al.*, 1967). During both the seasons- though potential fecundity of the female was nearly same, repeated mating changed the egg laying and hatching. From repeated mating exploiting males up to 4 times during March-April shows that utilization of male up to 3 times have no harmful effect on fecundity as well as hatching. During September-October also, no significant variation has been observed between the egg laying of females mated with males utilized for the 2nd, 3rd and 4th time and after that decreases significantly and hatching also decreases from single mating to 5th time mating. However, no egg hatched from 6th time utilization. So, utilization of male up to 4th time during this season is effective in terms of egg laying and hatching.

Both the results have clear conformity with Benchamin *et al.* (1990), according to them in *Bombyx mori* the fecundity is comparable in the first 4 matings but reduces in 5th and 6th mating and with Ojha *et al.* (1996) trying the repeated mating in *Antheraea mylitta* where they have been found that females lay eggs even when mated with 4 × males. Repeated mating lead to inadequate discharge of spermatic fluid and result in reduced fecundity (Sidhu *et al.*, 1967). This is also reflected in terms of reduced laying and fertility percentage in the present study. Earlier studies also indicate that viability of eggs is not affected significantly up to four matings of male moths (Subramanyam, 1982).

Therefore, in muga culture, as synchronization of male and female is one of the principal constraints of egg production, the problem can be overcome through repeated exploitation of male moth up to four times prior to main commercial crop rearing season and up to three times before second commercial rearing by artificial coupling for seven hours which will ultimately supply higher number of quality eggs to the farmers.

ACKNOWLEDGMENT

The financial assistance provided by University Grants Commission, New Delhi in carrying out this research work is gratefully acknowledged

REFERENCES

BENCHAMIN K.V.; MAGADUM S.B. & SHIVASHANKAR N. (1990). Mating capacity of male moths of pure breeds and hybrids in silkworm *Bombyx mori* L. Indian J. Seric. 29(2) : 182-187.

KHANIKOR D.P. & DUTTA S.K. (1998). Low temperature preservation of seed cocoons for delaying moth emergence in muga silkworm (*Antheraea assama* Westwood) (Lepidoptera Saturniidae). Proc. of The 3rd International Conference on Wild Silkmoths, Bhubeneshwar, Orissa, November 11-14.

SAHU M.; MUKHERJEE P.K. & MONDAL T. (1998). Constraints during pre-seed crop rearing of *Antheraea assama* Ww. at seed rearers level in lower Assam. Proc. of The 3rd International Conference on Wild Silkmoths, Bhubeneshwar, Orissa, November 11-14.

SAMSON M.V. BARAH A. (1989). Suggestion for Better Muga Seed Production. Indian Silk. June 1989, 15-16.

SIDHU N.S.; SREENIVASAN R. & SHAMACHARY (1967). Fertility performance of female moths depends on their male moths. Indian J. Seric. 1(2) : 77-84.

SUBRAMANYAM K. (1982). Studies on the effect of rest on the efficiency of male moths in relation to number of mating and occurrence of viable eggs in silkworm *B. mori.* L. STS dissertation submitted ICTRETS, C.S.R & T.I, Mysore, 14-15.

OJHA N.G.; SHARAN S. K.; RAVIKUMAR G.; DUBEY O.P.; SINHA B.R.R.P. & SINHA S. S. (1996). Effect of refrigeration on mating efficiency of male moths of Tasar silkworm, *Antheraea mylitta* D. Indian J. Seric. 35(2) : 155-157.

Research Paper *Indian J. Seric., 2005, Vol. 44, No. 1, 107-112.*

STUDIES ON REARING PERFORMANCE OF MUGA SILKWORM (*ANTHERAEA ASSAMA*) IN TERAI REGION OF WEST BENGAL (INDIA) - A NEWLY EXPLORED AREA

N. Ray[1], I. Biswas[2], Bhattacharya[3], S. K. Das[4] and P. K. Das[5]

[1,2,3]Muga Research Laboratory, A. B. N. Seal College, Coochbehar - 736 101, India.
[4] Office of the Deputy Director of Sericulture, Coochebhar - 736 101, India.
[5] RDO (NE), Central Silk Board, Guwahati - 781 005, India.

(Received: 3 June, 2004; Accepted: 28 June, 2005)

A preliminary investigation on muga silkworm (*Antheraea assama* Westwood) rearing as well as grainage was undertaken during nine different seasons (February-March, April-May, May-June, July-August, August-September, October-November, November-December, December-February, and January-March) during 2000-2003 to identify the suitable season for commercial and seed crop rearing for successful introduction of mugaculture in Terai region of West Bengal, India, a newly explored area. Rearing and grainage parameters were better during Oct. - Nov. (Effective rate of rearing: 49.20 %, Yield: 32.07 kg, Fecundity: 283, Hatchability: 98.87 %) followed by Apr. - May and minimum during July - Aug. (Effective Rate of Rearing: 10.60 %, Yield: 6.39 kg, Fecundity: 188, Hatchability : 6.24 %).

Key words: Effective rate of rearing, fecundity, muga silkworm, seed crop, yield.

INTRODUCTION

In the perspective of rural poverty and unemployment, low productive agriculture and industrial backwardness in Terai region of West Bengal, India, the sericulture in general and mugaculture in particular may appear to have special relevance for the economic uplift of rural people. Till date, mugaculture is mainly confined to the Brahmaputra valley of Assam and foothills of East Garo hills of Meghalaya mainly due to the unique climate and natural abundane of food plants in North Eastern India (Thangavelu *et al.*, 1988; Samson and Barah, 1989). The climatic condition of Cooch Behar district and a part of Jalpaiguri district of Terai region of West Bengal is to some extent similar to that of Assam which may favour muga culture in commercial scale in this region (Isa and Samson, 1987; Singha *et al.*, 1991; Ray, 2003). Hence Central Silk Board and State Sericulture Department, Government of West Bengal try to introduce mugaculture in the region. It is well established that regional variation in climate influences the rearing of mulberry silkworm, *Bombyx mori* (Venugopala Pillai and Jolly, 1985; Muslin, 1986; Rahman and Ahmed, 1988; Roy Chowdhuri *et al.*, 1992; Ray *et al.*, 2000) which may be true for muga silkworm, *Antheraea asama* also. Since investigation has not been done till date in the zone under consideration, the present study was undertaken to identify the commercial crop and seed crop rearing seasons for successful mugaculture in the region.

MATERIALS AND METHODS

Cooch Behar district of West Bengal is under Terai region and is situated in the north eastern part of West Bengal, adjacent to Goalpara district of Assam. It lies between 26° 57'40" to 26° 32'20" North latitude and 88° 47'40" to 89° 54'35" East longitude. The altitude of the district is 43 m above MSL.

The meteorological data are given in Table 1. Muga silkworm rearing (9 crops) was conducted during all the seasons under consideration, namely, February-March, April-May, May-June, July-August, August-September, October-November, November-December, December-February and January-March. Rearing parameters such as larval period, mature larval weight (male and female), single cocoon weight (male and female), single shell weight (male and female), shell ratio, effective rate of rearing in number, absolute silk content and yield / 10,000 brushed larvae were recorded during all the 9 crops. Grainage parameters like potential fecundity, realized fecundity and hatchability (%) were also observed in all the seasons. The experimental rearings were conducted during 2000-2003 at Khagrabari Extension centre (Cooch Behar, West Bengal), Regional Muga Research Station (Boko, Asam), Central Silk Board, India as well as at Khagrabari State Sericulture Farm (Cooch Behar, West Bengal), Govt. of West Bengal and grainage and other studies were conducted at Muga Research Laboratory, A. B. N. Seal college, Cooch Behar. Data obtained from each rearing were recorded and analyzed statistically.

RESULTS

Seasonal influence on rearing performance: Seasonal influence on rearing performances as reflected by larval

Table 1: Mean meteorological data (2000-2003).

Season	Photoperiod (h)		Temperature (°C)		Humidity (%)		Rainfall
	Light	Dark	Max.	Min.	Max.	Min.	(mm)
March - April	12.19	11.41	25.57	19.72	72.20	58.02	57.53
April - May	12.45	11.15	29.77	23.52	73.35	62.82	164.43
May - June	13.09	10.51	31.77	25.97	77.57	69.30	506.94
June - July	13.20	10.40	32.30	27.17	82.87	75.16	725.44
July - Aug.	13.04	10.56	32.24	26.84	81.17	75.69	571.17
Aug. - Sept.	12.40	11.20	31.85	25.99	80.15	75.05	381.15
Sept. - Oct.	12.50	11.10	29.40	23.98	78.76	72.98	294.18
Oct. - Nov.	11.15	12.45	26.91	19.24	75.41	70.53	42.32
Nov. - Dec.	10.45	13.15	24.14	13.97	74.02	68.45	5.77
Dec. - Jan.	10.39	13.21	20.02	10.57	75.32	64.45	9.47
Jan. - Feb.	10.51	13.09	19.80	11.27	79.10	61.37	15.57
Feb. - March	11.30	12.30	24.07	15.17	75.73	57.80	37.23

(Source: State Meteorological Department, Cooch Behar and CSB Extension Centre, Cooch Behar.)

Table 2: Effect of seasons on rearing performances of muga silkworm.

Rearing parameter / Season	Larval duration (days)	Weight of single mature larva (g)		Single cocoon weight (g)		Single shell weight (g)		Shell %		ERR/ No.	Absolute silk content (kg)	Yield/ 10,000 larvae brushed (kg)
		♂	♀	♂	♀	♂	♀	♂	♀			
Feb.-March	25.00	7.02	11.00	4.75	7.02	0.330	0.430	7.06	6.12	31.20	1.19	18.35
April - May	24.00	6.96	11.30	4.49	7.77	0.350	0.444	7.86	5.71	43.40	1.74	26.61
May - June	23.90	6.38	10.24	4.23	7.23	0.330	0.440	7.75	6.11	35.40	1.36	20.23
July - Aug.	23.60	6.47	10.70	4.38	7.66	0.324	0.436	7.40	5.69	10.60	0.40	6.39
Aug. - Sept.	24.40	7.05	11.17	5.01	7.72	0.354	0.450	7.08	5.99	27.80	1.12	17.70
Oct. - Nov.	27.20	7.61	11.97	5.19	7.84	0.338	0.496	6.45	6.32	49.20	1.95	32.07
Nov. - Dec.	35.60	7.24	11.51	4.62	7.27	0.340	0.444	7.35	6.10	39.60	1.55	23.54
Dec. - Feb.	58.80	7.10	10.11	3.98	5.95	0.306	0.408	7.69	6.85	24.20	0.87	12.02
Jan.- March	55.60	6.83	9.75	3.50	5.50	0.282	0.356	8.05	6.47	19.80	0.63	8.93
CD at 5 %	10.94	0.14	0.24	0.17	0.19	0.041	0.049	0.60	0.41	5.01	1.02	2.94

duration, single cocoon weight, single shell weight, shell ratio, absolute silk content, effective rate of rearing and yield are depicted in Table 2.

Table 3: Effect of seasons on grainage performances of muga silkworm.

Season	Potential fecundity (no.)	Realised fecundity (no.)	Laying (no.) up to 3rd day	Egg retention (no.)	Hatchability (%)
Feb.-Mar.	240.00	238.00	204.00	2.00	97.06
April - May	254.40	251.20	216.80	3.20	44.79
May - June	235.20	230.00	204.40	5.20	20.88
July - Aug.	235.40	188.00	162.80	47.40	6.24
Aug. - Sept.	241.80	230.20	179.80	11.60	63.03
Oct. - Nov.	285.60	283.80	222.80	1.80	98.87
Nov. - Dec.	250.00	245.00	200.40	5.00	97.37
Dec. - Feb.	200.80	193.00	151.80	7.80	97.80
Jan - March	203.80	200.00	146.80	3.40	98.20
CD at 5 %	11.48	12.13	3.18	4.29	2.52

Larval duration

The larval duration was the longest during Dec.-Feb. (58.80) days) followed by that of Jan.-Mar. (55.60 days), Nov.-Dec. (35.60 days) and Oct.-Nov. (27.20 days). The larval duration for the remaining months were observed between 23.60-27.20 days. No significant difference was observed between that of Feb.-Mar., Apr.-May, May-June and Aug.-Sept. (23.90-25.0 days). The shortest larval duration was observed during July-Aug. (23.60 days) having non-significant difference with that of Aug.-Sept. (24.40 days).

Larval weight

As male and female mature larval weight vary greatly in muga silkworm, the larval weight for male and female was recorded separately.

Weight of mature male larvae: Significantly high weight was observed during Oct.-Nov. (7.61 g) followed by Nov.-Dec. (7.24 g). No significant difference was observed between values recorded during Dec.-Feb. (7.10 g), Aug.-Sept. (7.05 g), Feb.-Mar. (7.02 g) and Apr.-May (6.96 g). Also, there was no significant variation between that of Apr.-May and Jan.-Mar. (6.83 g). The lowest weight was observed during May-June (6.38 g) having non-significant difference with that of July-Aug. (6.47 g).

Weight of mature female larvae: The highest mature female larval weight was recorded during Oct.-Nov. (11.97 g) followed by Nov.-Dec. (11.51 g). Non-significant difference was observed between that of Nov.-Dec. and Apr.-May (11.30 g). Mature female larval weight was higher during Feb.-Mar. (11.00 g). Significantly lowest female larval weight was observed during Jan.-Mar. (9.75 g).

Single cocoon weight

Cocoon weight also varied between male and female population in muga silkworm.

Single cocoon weight (male): Male cocoon weight varied from 3.5 to 5.19 g during different seasons having significant variations. The highest male cocoon weight was obtained during Oct.-Nov. (5.19 g) followed by Aug.-Sept. (5.01 g) and Feb.-Mar. (4.75 g). However, there was no significant difference between that of Feb.-Mar. and Nov.-Dec. (4.62 g). Significantly lowest male cocoon weight was recorded during Jan-Mar. (3.5 g).

Single cocoon weight (female): Female cocoon weight varied from 5.50 to 7.84 g. The highest female cocoon weight was recorded during Oct.-Nov. (7.84 g). During Jan.-Mar., a low female cocoon weight was recorded (5.50 g).

Shell weight

Male shell weight varied from 0.282 to 0.354 g having non significant variation during different seasons. Female shell weight varied from 0.356 to 0.496 g having non-significant difference during different seasons. The highest female shell weight was observed during Oct.-Nov. (0.496 g) followed by Aug.-Sept. (0.450 g). During Jan.-Mar., both male (0.282 g) and female (0.356 g) shell weights were recorded the lowest. Regarding average shell weight, non significant differences were observed during all the seasons (0.402 - 0.378 g) except during Dec.-Feb. when it was 0.357 g and during Jan.-Mar. when it was 0.319 g which was the lowest.

Shell %

Shell % was observed higher in male (6.45 - 8.05 %) than in female (5.68 - 6.85 %). The highest SR % was obtained during Jan.-Mar. (8.05 %) for male cocoon and during Dec.-Feb., for female cocoon (6.85 %).

Effective rate of rearing (ERR / No.)

The economic output of muga silkworm rearing as reflected by effective rate of rearing in number (ERR) showed significant variations among the seasons. ERR during Oct.-Nov. recorded the best (49.20 %) followed by that in Apr.-May (43.40 %). The ERR was also good during May-June (35.40 %). Lowest ERR was observed during July-Aug. (10.60 %) followed by Jan.-Mar. (19.80 %).

Absolute silk content

From the qualitative point of view, absolute silk content was calculated (per 10,000 larvae brushed) and it was observed the highest during Oct.-Nov. (1.95 kg) followed by Apr.-May (1.74 kg). Absolute silk content during Nov.-Dec. was also better (1.55 kg) having non-significant difference with that in Apr.-May. The silk content during May-June was also good (1.36 kg). However, the lowest performance was obtained during July-Aug. (0.40 kg) followed by winter months.

Yield

Cocoon yield was calculated per 10,000 larvae brushed. The highest cocoon yield was recorded during Oct.-Nov. (32.07 kg) followed by Apr.-May (26.61 kg). Yield during May-June (20.23 kg) and Nov.-Dec. (23.54 kg) was also good. The lowest yield was observed during July-Aug. (6.39 kg).

From the above results it was found that almost all the rearing parameters were observed better during Oct.-Nov. and the worst during July-Aug.

Seasonal influence on grainage performance: Seasonal influence on grainage performances as reflected by potential fecundity, realized fecundity and hatching percentage are depicted in Table 3.

Potential fecundity

Significant variation was observed among the seasons. Significantly highest potential fecundity was recorded during Oct.-Nov. (285.60) followed by Apr.-May (254.40) and Nov.-Dec. (250.00). It was found nearly the same during Mar.-Apr. and Aug.-Sept. (240.00 and 241.80, respectively) and also during May-June and July-Aug. (235.20 and 235.40, respectively). During Dec.-Feb., the potentiality was the lowest (200.80) followed by Jan.-Mar. (203.80).

Realized fecundity

Realized fecundity was also observed significantly highest during Oct.-Nov. (283.80) followed by Apr.-May (251.20), Nov.-Dec. (245.00). The lowest realized fecundity was observed during July-Aug. (188.00) when the egg retention inside the female body was maximum (47.40). During Dec.-Feb. (193.00) and Jan.-Mar. (200.00), realized fecundity was also low. However during May-June and Aug.-Sept., the realized fecundity was at par (230. 00 and 230.20, respectively).

However, as per usual recommendation regarding effective collection of eggs up to three days to minimize the length of rearing and to synchronize the mating, data were recorded up to three days which reflected the same trend like realized fecundity *i.e.,* the best during Oct.-Nov. (222.80) followed by that in Apr.-May (216.80) and the lowest during Jan.-Mar. (146.80).

Hatchability

Hatching percentage was observed the highest during Oct.-Nov. (98.87 %) followed by Jan.-Mar. (98.20 %), Dec.-Feb. (97.80 %), Nov.-Dec. (97.37 %) and Mar.-Apr. (97.06 %). During May-June, the hatching percentage was very poor (20.88 %) and during July-Aug. almost no egg hatched (6.24 %).

Seasonal influence on grainage parameters was also observed better during Oct.-Nov. and the worst during July-Aug.

DISCUSSION

After careful observation it was found that the larval duration was observed longer during Dec.-Mar., which may be due to low temperature and shorter light period in winter seasons (Ochieng'-Odero, 1992; Sweeney and Vannote, 1981). During the rest of the seasons, the larval duration varied from 23.60 days to 27.20 days. Both male and female larval weights were higher during Oct. to Dec., may be due to longer larval period. Effective rate of rearing, the ultimate economic output to the farmers, was better during Oct.-Nov. followed by Apr.-May due to low disease occurrence. Regarding ERR and cocoon weight, Oct.-Nov. was the best followed by Apr.-May., Nov.-Dec. also showed better yield. Yield of May-June was also good.

From the meteorological data, it can be noticed that during Oct.-Nov., the temperature ranges from 26.91 to 19.24°C and humidity from 75.41 to 70.53 % and during Apr.-May it is 29.77 to 23.52°C and humidity from 73.35 to 62.82 % which are the optimum temperature and humidity ranges for muga culture (Thangavelu *et al.*, 1988). Fall of temperature and humidity after Oct.-Nov. and rise of temperature and humidity after Apr.-May affect effective rate of rearing as well as cocoon yield. Both ERR and yield were the highest during Oct.-Nov. in Assam also followed by May-June (Sahu *et al.*, 1998).

So, the ideal season for commercial rearing in Terai region of West Bengal is Oct.-Nov. and Apr.-May. The food plants may be utilized in Nov.-Dec. and May-June also if leaf and seed are available. Winter months from mid Dec. to mid Feb. should be avoided. The season, Feb.-Mar. may be utilized mainly as for seed production crop for supply during Apr.-May rearing. During rainy months (June to August), the rearing should be avoided. Only multiplication and maintenance of stock can be undertaken during rainy and winter months.

Grainage parameters (fecundity and hatchability) were also superior during Oct.-Nov. due to optimum temperature (19.24 to 26.91 °C), humidity (70.53 to 75.41 %) and photoperiod (11.15 L : 12.45 D) (Thangavelu *et al.*, 1988; Mahanta and Goswami, 1986). But during Apr.-May, though fecundity was high, hatchability was not good which may be due to longer light period as compared to hatchability during winter months having longer dark period.

However, for supply of seed during Apr.-May and Oct.-Nov., rearing seasons of Feb.-Mar. and Aug.-Sept. should be utilized. During Apr.-May rearing, sufficient number of seed can be supplied from Feb.-Mar. (231 hatched larvae/laying), but during main commercial crop rearing season, seeds from Aug.-Sept. rearing result in 140 hatched larvae from one dfl due to poor hatchability. This problem is also faced by Assam (Sahu *et al.*, 1998; Khanikor and Dutta, 1998) and for that reason, rearing status of Aug.-Sept. should be improved, or large scale rearing should be done during Aug.-Sept. for steady supply of seed for main commercial crop rearing.

From the results it can be suggested that for successful mugaculture in Terai region of West Bengal especially in Cooch Behar and Jalpaiguri districts, commercial crop should be reared during Oct.-Nov. and April-May and seed crop during Feb.-March and Aug.-Sept.

ACKNOWLEDGEMENT

The investigators are grateful to University Grants Commission, New Delhi for financial assistance through Major Research Project on Mugaculture, to Central Silk Board, Govt. of India for supply of seed and seed cocoon and to State Sericulture Farm, Govt. of West Bengal for providing muga food plantation for this experiment.

REFERENCES

Khanikor, D. P. and Dutta, S. K. (1998) Low temperature preservation of seed cocoons for delaying moth emergence in muga silkworm (*Antheraea assama* Westwood) (Lepidoptera: Saturniidae). *3rd International Conference on Wild Silkmoths*, 11-14 November, Bhubaneshwar, Orissa, India, p.73.

Mahanta, H. C. and Goswami, M. C. (1986) Some aspects of influence of photoperiod on muga silkworm, *Antheraea assama* Westwood (Lepidoptera: Saturniidae). *Uttar Pradesh Journal of Zoology*, **6(1)**: 98-107.

Isa, M. and Samson, M. V. (1987) Muga culture finds new fields in West Bengal. *Indian Silk*, **26(4)**: 47-48.

Muslin, M. M. (1986) Trials on multiple silkworm rearing in spring-post spring seasons in Pakistan. *Pak. J. For.*, **36(1)**: 5-8.

Ochieng'-Odero, J. P. R. (1992) The effect of three constant temperatures on larval critical weight, latent feeding period, larval maximum weight and fecundity of *Cnephasia jactatana* (Walker) (Lepidoptera: Tortricidae). *J. Insect Physiol.*, **38(2)**: 127-130.

Rahman, S. M. and Ahmed, S. U. (1988) Stability analysis for silk yield in some promising genotypes of silkworm *Bombyx mori* L. *International Congress on Tropical Sericulture Practices*, Bangalore, February, 18-28.

Ray, N. (2003) Muga steps in West Bengal. *Recent Advances in Animal Science Research*, Orion Press International, India, **2**: 284-288.

Ray, N.; Senapati, S. K. and Deb, D. C. (2000) Studies on the combined effect of mulberry varieties and seasons on performances of bivoltine silkworm, *Bombyx mori* in Terai zone of West Bengal. *Indian J. Enotomol.*, **62(1)**: 60-65.

Roy Chowdhuri, S.; Rajanna, L.; Subba Rao, G. and Mani, A. (1992) Impact of climatic factors on the rearing performance of bivoltine at Nilgiri hills, Tamilnadu. *National Conference on Mulberry Sericulture Research*, December, 10-11.

Sahu, M.; Mukherjee, P. K. and Mondal, T. (1998) Constraints during pre-seed crop rearing of *Antheraea assama* Ww. at seed rearers level in lower Assam. *3rd Internaional Conference on Wild Silkmonths,* 11-14 November, Bhubaneswar, Orissa, India, p.32.

Sahu, A. K.; Singha, B. B. and Das, P. K. (1998) Phenological studies in muga silkworm *Antheraea assama* Ww. (Lepidoptera: Saturnidae) in relation to its rearing and grainage behaviour. *3rd International Conference on Wild Silkmoths,* 11-14 November Bhubaneswar, Orissa, India, p.3.

Samson, M. V. and Barah, A. (1989) Suggestions for better muga seed production. *Indian Silk,* **28(2):** 15-16.

Singha, B. B.; Lepcha, S. T. and Pramanik, A. T. (1991) Muga finds its way to West Bengal. *Indian Silk,* **30(5):** 41-43.

Sweeney, B. W. and Vannote, R. L. (1981) *Ephemerella* mayflies of White Clay Creek: bioenergetic and ecological relationships among six coexisting species. *Ecology,* **62:** 1353-1369.

Thangavelu, K.; Chakraborty, A. K.; Bhagowati, A. K. and Md. Isa. (1988) *Hand book of muga culture,* Central Silk Board.

Venugopala Pillai, S. and Jolly, M. S. (1985) An evaluation of quality of mulberry varieties under hill conditions and crop results of *Bombyx mori. Indian J. Seric.,* **24:** 48-52.

J. Exp. Zool. India Vol. 10, No. 2, pp. 271-276, 2007 *ISSN 0972-0030*

STUDIES ON SHORT-TERM COLD PRESERVATION FOR SUPPLY OF SEED DURING MAIN COMMERCIAL CROP REARING OF MUGA SILKWORM

Indrajit Biswas and Nilay Ray

Muga Research Laboratory, Department of Zoology, A.B.N. Seal College, Cooch Behar - 736101, India.

(Accepted 30 May, 2006)

ABSTRACT – An attempt has been made to avoid rearing during mid June to mid August reflecting poor supply of seed during main commercial season (October-November) by refrigerating the cocoons from previous commercial crop (May-June) to supply sufficient seed for commercial rearing. From the results it can be said that 15 days cocoon preservation from proceedings commercial crop rearing can delay the moth emergence for 10 days, subsequent adult moth preservation for 5 days show almost no deleterious effect on fecundity and hatchability. The eggs thus obtained if preserved after 24 hrs. for 21days can delay the hatching for 24 days. This experiment provided a schedule of rearing for better supply of seed during the main commercial crop rearing during October-November by maintaining the schedule of preservation package collecting the cocoons from commercial crop of May-June avoiding the adverse seasons. Moreover, only 35 paise/dfl. additional expenditure is required to supply adequate amount of healthy seed to the farmers for main commercial crop rearing during October-November.

Key words- muga silkworm, cold preservation, seed.

INTRODUCTION

For the success of sericulture industry, proper supply of silkworm eggs (seed) is essential. The hatching period of eggs must coincide with the availability of suitable leaves as well as environmental conditions. This problem is more acute in muga culture as the environmental conditions during mid June to mid August is quite adverse for rearing and as a result main commercial crop rearing during October-November suffers badly due to poor supply of seed (Samson and Borah, 1989; Sahu, 2003). Therefore, the hatching of larva has to be controlled, accelerated or postponed by artificial treatment under the refrigerated condition. In the life cycle of silkworm refrigeration is usually restored to all the four steps of development viz. egg (Yokoyama, 1962; Dutta *et al*, 1972; Tazima, 1978), larva (Yokoyama, 1962; Tazima, 1978), cocoon/pupa (Yokoyama, 1962; Tanaka, 1964; Kovala, 1970) and moth (Tazima, 1978; Ayuzawa *et al*, 1972). In muga silk worm, cocoon refrigeration at 7±1°C can delay moth emergence upto 30-40 days (Khanikor and Dutta, 1998), preservation of adult moth at 10±1°C can delay the coupling upto 7 days (Biswas and Ray, 2003) and cold preservation of 36 hours eggs can delay the hatching up to 36 days (Singha *et al*, 1998). Keeping these findings i.e. refrigeration of cocoon, moth and egg can delay the egg hatching under consideration, an attempt has made to avoid rearing during mid June to mid August reflecting poor supply of seed during main commercial season (October-November) by refrigerating the cocoons from previous commercial crop (May-June) to supply sufficient seed for commercial rearing.

MATERIALS AND METHODS

Cocoons were collected from Extension Centre, Regional Muga Research Station, Central Silk Board, Cooch Behar from commercial crop of May-June. Cocoons were preserved at 10±1°C upto 21 days and emergence was recorded. Subsequently the moths were preserved at 10±1°C upto 7 days and their grainage activities were recorded. Eggs laid by the females were collected for low temperature preservation at 10±1°C after 12, 24, 36 and 48 hrs. of egg laying for 7, 15, 21 and 30 days. Simultaneously a batch of cocoons and eggs were allowed to emerge and hatch respectively in normal condition and treated as control. Larva thus obtained then reared for supply of seed during October-November. Larvae thus obtained then reared for supply of seed during October-Nov. The experiment was conducted at Muga Research Laboratory, A.B.N. Seal College, Cooch Behar during 2001-2005. Data thus obtained were analysed statistically.

RESULTS

On Cocoon Preservation :

Effect of short term cold preservation on cocoon was recorded as pupal period and emergence percentage. (Table-1)

Pupal Period

In natural condition (Control), pupal period was

The success of this experiment can able to provide a schedule of rearing for better supply of seed during the main commercial crop rearing during October-November.

Cocoon Collection	Commercial Crop Rearing	:	May-June
	Spinning	:	9th June
	Cocoon Preservation at 10±1°C	:	14th June
Preservation	Moth Emergence	:	6th July
	Moth Preservation at 10±1°C	:	6th July to 11th July
	Coupling and egg laying	:	12th July to 15th July
	Egg preservation at 10±1°C	:	13th July to 16th July
	Egg hatching	:	14th Aug. to 17th Aug.
	Seed crop rearing	:	14th Aug. to 10th Sept.
Seed Crop Rearing	Moth Emergence	:	29th September
	Coupling and egg laying	:	30th Sept. to 3rd Oct.
	Brushing for commercial rearing	:	8th Oct. to 11th Oct.
Main commercial rearing		:	**From 9th October**

Additional electrical expenditure calculated for 20,000 dfl seed for commercial rearing which can be affordable.

Additional expenditure : (as electricity charge)

Input			
Cocoon Preservation (2500 cocoon)	15 days	180.00/day x 15	2700.00
Adult Preservation (90% Emergence) (@ 2200)	5 days	540.00 / day x 5	2700.00
Egg Preservation (70% coupling & 210 fec.) @ 1000 dfl.	21 days	45.00 / day x 21	945.00
Total electricity charges (Rs. 3.00 per unit)	6345.00		
Output			
Seed crop rearing of 1000 dfl (having 70% hatching, 30% ERR and 230 realised fecundity)		20,000 dfl. Seed	
Additional expenditure (6345.00 , 20,000) or 32 paise @ 35 paise. / dfl.			

found 17.33 days for male and 18.33 days for female. No adult was emerged after 18 days. After short term preservation of seed cocoon at 10±1°C, the pupal period has been lengthened for both male and female. It was observed that longer the preservation days longer the pupal period upto 18th day. Longest pupal period was observed for 17 days preservation which was 9.33 days and 8.67 days more over control for male and female respectively. However, there observed no significant difference between 11 to 18 days in male and 13 to 18 days in female.

Emergence Percentage

Emergence percentage was found higher over control than preserved for more than 2 days to 8 days. However, 90 to 96% emergence was observed upto 15 days preservation and in control. A drastically decreased emergence was observed after 16 days (85%) when it was 30% in 17th days and only 10% in 18 days preservation and after that emergence was nil.

Table-1 : Effect of seed cocoon preservation at 10±1°C on pupal period and emergence percentage of muga silkworm.

Cocoon Preservation Days	Pupal period after preservation		Emergence %
	Male	Female	
1	18.33	18.67	92.00
2	19.00	19.67	92.00
3	19.67	21.00	96.00
4	21.00	22.00	96.00
5	22.00	22.33	96.00
6	23.67	23.67	93.00
7	24.33	24.67	93.00
8	24.33	24.67	93.00
9	24.33	25.00	90.00
10	24.67	25.67	90.00
11	25.33	25.67	90.00
12	25.33	25.67	90.00
13	25.67	26.33	90.00
14	26.33	26.67	90.00
15	26.33	26.67	90.00
16	26.67	27.00	85.00
17	26.67	27.00	30.00
18	26.00	26.33	10.00
Control (Fresh)	17.33	18.33	92.00
CD at 5%	1.432	1.444	0.739

Table 4 : Rearing performance during different seasons.

Seasons	ERR. No.	Pupal Period (days)	Realized Fecundity (no.)	Incubation Period (days)	Hatchability (%)
June-July	8.20	16.67	170.00	8.00	7.21
July-August	10.60	16.89	188.00	8.00	6.24
Aug.-Sept.	30.80	17.67	230.00	8.33	63.03
C. D at 5%	2.090	1.196	10.22	1.505	1.70

Taking emergence percentage as well as delayed pupal period under consideration, adult moths from 15 days preserved cocoon was selected for adult preservation.

On Adult Preservation

Effect of adult preservation was recorded as coupling efficacy, realized fecundity and hatchability. (Table-2)

Coupling efficacy : No significant variation was observed between the coupling efficacy of fresh coupling (control) (96.67%) and upto 3 days of adult preservation (90%-96.67%). Significant variations were observed in all other cases and from 6 days and above the coupling efficacy were observed very low.

Table-2 : Effect of adult preservation at 10±1°C on coupling efficacy, fecundity and hatchability of muga silkworm.

Adult Preservation Period	Coupling efficacy	Fecundity	Hatchability
1 day	96.67	242	88.66
2 days	96.78	240	89.40
3 days	90.00	225	87.16
4 days	80.00	220	80.18
5 days	70.00	210	78.30
6 days	36.67	200	65.28
7 days	23.33	189	63.18
Fresh x Fresh (Control)	96.67	245	88.79
CD at 5 %	9.53	**3.53**	8.48

Table 3 : Effect of seed preservation of different hours of laying at at 10±1°C on incubation period and hatching percentage of muga silkworm.

Hrs. after laying	Preservation period (days)	Incubation period (days)	Days delayed	Hatching %
12 hours	7	18.33	10.33	86.33
	15	27.00	19.00	85.00
	21	32.33	24.33	42.75
	30	–	–	–
24 hours	7	18.33	10.33	83.76
	15	27.67	19.67	73.30
	21	32.33	24.33	70.28
	30	–	–	–
36 hours	7	18.67	10.67	79.33
	15	28.33	20.33	70.67
	21	31.33	23.33	60.33
	30	–	–	–
48 hours	7	19.33	11.33	75.67
	15	24.33	16.33	68.33
	21	29.33	21.33	49.67
	30	–	–	–
C.D. at 5%	Hrs. after laying	**0.263**	**0.263**	**0.201**
	Preserve Period	**0.228**	**0.228**	**0.151**
	Hrs. after laying x preserve period	**0.457**	**0.457**	**0.604**

Fecundity

As the preservation day increased fecundity decreased. Highest fecundity was observed in control (245) having nonsignificant difference with 1 day and 2 days preservation, lowest being from 7 days (189).

Hatchability

Hatchability also followed the similar trend. Significantly highest hatchability was obtained from control (88.79%) and upto 3 days of adult preservation (87.16% - 88.66%) followed by preservation of 4 and 5 days (78.30% - 80.18%) adult preservation. Significantly lowest hatchability was observed from 7 days preservation (63.18%).

From overall results, it can be said that eggs from 5 days preserved adult can be selected for preservation so far as delayed hatching is concerned.

On Egg Preservation

Eggs obtained from 5 days adult preservation was collected after 12 hrs., 24 hrs., 36 hrs. and 48 hrs. and preserved for 7, 15, 21 and 30 days. Incubation period, days delayed (control : 8 days) and hatching percentage were recorded. (Table-3)

Incubation period

Incubation period could not be recorded for 30 days preservation as no larva was hatched. Highest incubation periods was observed when 12hrs./24hrs. eggs were preserved for 21 days (32.33 days) followed by 36hrs. for 21 days (31.33 days). Lowest incubation period was observed when 12hrs./24hrs. eggs were preserved for 7 days (18.33days)

Days delayed

When 12hrs./24hrs. eggs were preserved for 21 days hatching delayed for 24.33 days followed by 36 hrs egg preserved for 21 days (23.33 days) and by 48 hrs egg preserved for 21 days (21.33). Lowest delay was observed from the eggs of 12hrs./24hrs when preserved for 7 days (10.33 days).

Hatching Percentage :

Hatching percentage showed significant difference. Highest hatching percentage was found from the eggs of 12hrs. and preserved for 7 days and lowest from 12hrs. preserved for 21 days. Eggs of 24 hrs. when preserved for 21 days showed 70.28% hatching while in the eggs of 36 hrs preserved to 21 days showed 60.33% hatching. However 48hrs. egg when preserved for 21 days showed only 49.67% hatching.

Muga Silkworm survivability & egg production during adverse months

Larva thus hatched were reared during August-September and ERR No., fecundity and hatchability were recorded, alongwith the performances (Table-4) during adverse months.

Effective Rate of Rearing

ERR was observed very poor during June-July and July-August. However, ERR increased during August-September (30.80%)

Realised fecundity

Fecundity was observed highest during August-September (230.00) followed by July-August (188.00) and June-July (170.00).

Hatchability

Hatching percentage during June-July (7.21%) and July-August (6.24) was very poor, nearly no larva could hatch. However, 63.03% larvae were hatching during August-September.

DISCUSSION

Successful muga culture needs sufficient supply of seed during commercial rearing. Pre-seed crop rearing season for main commercial crop rearing suffers very much due to adverse environmental conditions i.e. very high temperature and humidity alongwith heavy rainfall during mid June to mid August. Attempts should be made to skip these months by any means. In this investigation short term cold preservation at 10±1°C can formulate a package to overcome this stress investigating all the loop holes including the economic investment.

From the results it can be said that 15 days cocoon preservation from proceedings commercial crop rearing can delay the moth emergence for 10 days, subsequent adult moth preservation for 5 days show almost no deleterious effect on fecundity and hatchability. The eggs thus obtained if preserved after 24 hrs. for 21days can delay the hatching for 24 days. These results have conformity with the earlier findings of Khanikar and Dutta, 1998; Biswas & Ray, 2003 and Singh *et al*, 1998. Though they exploited only one stage for preservation and cold shock was maintained much lower than this experiment (10±1°C). The eggs thus brushed will be reared for supply of seed for commercial rearing. The grainage performance was also observed satisfactory.

So, by maintaining the schedule and preservation package collecting the cocoons from commercial crop of May-June the adverse seasons can be avoided as well as only 35 paise/dfl. additional expenditure/dfl is required to supply adequate amount of healthy seed to the farmers for main commercial crop rearing during October-November.

ACKNOWLEDGEMENT

Authors are grateful to the University Grants Commission, New Delhi for financial assistance through Major Research Project.

REFERENCES

Ayuzawa C, Sekido I, Yamakawa K, Sakuri U, Kuruva W, Yaginuma Y and Tokovo Y (1972) *Hand book on Silkworm Rearing.* Fuji Publishing Company, Toyo, Japan.

Biswas I and Ray N (2003) Exploitation of muga culture in terai region of West Bengal, a non-traditional area. *Proc. of 4th all India people's technology Congress*, February 23-24, Kolkata. pp. 86-90.

Dutta R K, Sengupta K and Biswas S (1972) Studies of preservation of multivoltine silk worm eggs at low temperatures. *Indian J. Seric.* 11, 20-27.

Khanikar D P and Dutta S K (1998) Low temperature preservation of seed cocoons for delaying moth emergence in muga silkworm. (*Antheraea assama* Westwood) (Lepidoptera: Saturniidae). *The 3rd International Conference on Wild Silk moths.* Bhubaneswar, Orissa. November 11-14.

Kovalev P A (1970) *Silkworm breeding stocks.* Central Silk Board. 112 (108-133)

Sahu A K (2003) Muga silkworm seed production : Constraints and strategies. *Indian Silk* 42(2), 14-17.

Samson M V and Barah A (1989) Suggestions for Better Muga Seed Production. *Indian Silk* 28(2), 15-16.

Singha B B, Sahu A K and Das P K (1998) Identification of low temperature registrant embryonic stages(s) in muga silkworm, *Antheraea assama* Ww. The 3rd International conference on Wild Silk moths, Bhubaneswar, Orissa, Nov. 11-14.

Tanaka Y (1964) *Sericology.* Central Silk Board, Bombay, India. pp 20-35.

Tazima (1978) *The silkworm: An important Laboratory Tool.* Published by Kodansha Ltd. Tokyo, Japan.

Yokayama (1962) *Synthasized sciences of sericulture.* Central Silk Board, Bombay, India. pp 210-223.

eggs longer preservation period have adverse effect on hatching and also needs lower temperature stress to get positive performance.

ACKNOWLEDGEMENT

Authors are grateful to University Grants Commission for their financial support through Research Project on mugaculture.

REFERENCES

Ayuzawa C, Sekido I, Yamakawa K, Sakuri U, Kuruva W, Yaginuma Y and Tokovo Y (1972) *Hand book on Silkworm Rearing*. Fuji Publishing Co. Tokyo.

Biram Saheb M N and Puttaswamy Gowda (1987) Silk worm seed technology, In: *Appropriate sericulture techniques*, Dr. M.S.Jolly (Ed.), Mysore, India.

Dutta R K, Sengupta K and Biswas S (1972) Studies on preservation of multivoltine silk worm eggs at low temperatures. *Indian J. Seric.* **11**,20-27

Furusawa T, Shimizu K and Yano T (1987) Polymol accumulation in Non-Diapause eggs of the silkworm, *Bombyx moriL. J. Sericult. Sc. Japan* **56**, 150-156.

Hiratsuka (1975) *Text book of Tropical Sericulture.* Japanese Overseas co-per. Volunters, Tokyo.

Jolly M S (1983) *Organization of Bivoltine Grainage for Tropics. Sericulture Project 3.*CSRTI, Mysore.

Khanikar D P and Dutta S K (1989) Low temperature preservation of seed cocoons for delaying moth emergence in muga silkworm (*Antheraea assama* Westwood) (Lepidoptera: Saturniidae).*The 3rd. Int. Conf. Wild Silk moths*, Bhubaneswar, Orissa..

Kovalev P A (1970) *Silkworm breeding stocks.* Central Silk Board, Bangalore, India.

Krishnaswamy S, Narasimhanna M , Suryanarayana S K and Kumara Raj S (1978) Manual on sericulture -2, Silkworm Rearing, F.A.O. Rome.

Narayanswamy T K and Govindan R (1987) Effect of refrigeration of eggs of pure Mysore of Silkworm *Bombyx mori* L, at blue stage. *Entomon* **12**, 105-107.

Pearse V, Pearse J, Buchsbaum M and Buchsbaum R (1987) In: *Living Invertebrates.* Blackwell Scientific Publication, Boston.

Sahu A K, Singha B B and Das K K(1997) Preservation of seed cocoon of muga silkworm, *Antheraea assama* Ww, at low temperature and high altitude. In: *Current Technology on non-Mulberry* Service, Ranchi.

Sahu A K, Singha B B and Das P K (1998) Identification of low temperature resistant embryonic stage(s) in muga silkworm, *Antheraea assama* Ww. *The 3rd. Int. Conf. Wild Silk moths*, Bhubaneswar, Orissa. November 11-14.

Sahu A K, Singha B B and Das P K(1998) Phenological studies in muga silkworm *Antheraea assama* Ww, Lepidoptera: Saturniidae) in relation to its rearing and grainage behaviour. *The 3rd. Int. Conf. Wild Silk moths*, Bhubaneswar, Orissa.

Sahu M, Mukherjee P K and Mondal T (1998) Constraints during pre-seed crop rearings of *Antheraea assama* Ww. at seed rearers level in lower Assam.

Tanaka Y (1964) *Sericology.* Central Silk Board. Bombay, India.

Tazima (1978) *The silk worm: An important Laboratory Tool.* Published by Kodansha Ltd. Tokyo, Japan.

Ullal S R and Narasimhanna M N (1978) *Hand book of Practical sericulture.* Central Silk Board, Bangalore, India.

Wang san-ming (1994) *Silkworm Egg Production.* Vol-III. Published by Food and agricultural Organization, United Nations.

Wei-hua Xu, Sato Y, Ikeda M and Yamashita O (1995) *J. biol. Chem.* **270**, 3804-3808

Yokayama (1962) *Synthasized sciences of sericulture.* Central Silk Board, Bombay, India.

Yuyin C (2000)Technical standards for commercial egg production of bivoltine silkworm varites used in China. *Sericologia* **40**, 185-201

which was below 50%. Moreover 24 hours laying for 21 days at 4 °C and 6°C also performed poorly which was only 50%.

When eggs of the 96 hours were preserved for 15 days, no egg was hatched at 8°C and 10°C. At the same time at 4°C and 6°C when eggs were hatched, the hatching percentage nearly 20% only. The result was also same for 12 days preservation of 96 hours eggs at 8oC and of 72 hours laying both at 8°C and 10°C. Better performances (99.90 to 88.90%, having non-significant difference) were obtained from most of the other treatments excepting 12 and 15 days preservation of 48 hours laying at 10°C and 96 hours laying at any temperature for 7 and 12 days preservation and 3 days preservation at 8°C.

DISCUSSION

Muga culture needs sufficient supply of seed during commercial rearing which is far below the target (Sahu *et al,* 1998a,b). Moreover the hatching period of eggs must coincide with the favourable environmental condition of commercial rearing. In this regard the hatching of larvae has to be controlled which may be done by low temperature stress on eggs. In mulberry sericulture a lot of research work has been initiated in this aspect which shows that eggs of 16-24 hours should be utilized for cold stress at 5°C for a maximum period of 8 days (Biram Saheb *and* Gowda , 1996; Wang San-ming, 1994; Jolly,1983; Tazima,1978; Ayuzawa *et al,* 1972) . Results from the present investigation in muga silkworm (*Antheraea assama*) also shows similarity with the works of mulberry silkworm. Among the four age group considered (24hours, 48 hours, 72 hours and 96 hours) eggs of 24 hours perform best in respect to delayed hatching with higher hatching percentage. When compared with the controlled incubation period of 7 days all the preservation period from 3 days to 21 days show longer incubation period, highest being from 21 days. Eggs of 24 hours when preserved for 21 days hatch after 26.10 days which is 19.10 days more than normal condition and hatching percentage is also better (99.10%) than in normal condition (82 %). Among all the temperature stress condition (4,6,8 and10°C), 10°C is the optimum for 24 hours egg, 8°C for 48 hours, 6°C for 72 hours and 4°C for 96 hours. Therefore from the result it can be said that higher the age of eggs, lower the temperature stress needed for successful cold preservation (fig.1&2). Moreover, as the age of the eggs progresses preservation period become shorter ¾ a maximum of 15 days for 48 hours egg and a maximum of 12 days and 96 hours egg (fig.3&4). Result reflects that if 48 hours egg are necessary for preservation, 15 days preservation at 8°C shows 18 days delayed hatching with higher hatching percentage and at 6°C shows 15 days delayed hatching with higher hatching percentage. A delayed hatching with high hatching percentage of 2 weeks can be done by 72 hours eggs when preserved for 15 days at 6°C. Delayed hatching (9-13 days) with satisfactory hatching percentage can be obtained from 96hours egg at 4°C when preserved for maximum of 12 days.

So it can be concluded that so far as egg preservation is concern, low temperature stress on muga silkworm egg can be exploited to control hatching period as and when needed.24 hours old egg at 10°C preserved for 21 days can delay hatching for 19 days having no deleterious effect on hatching percentage. More over for older

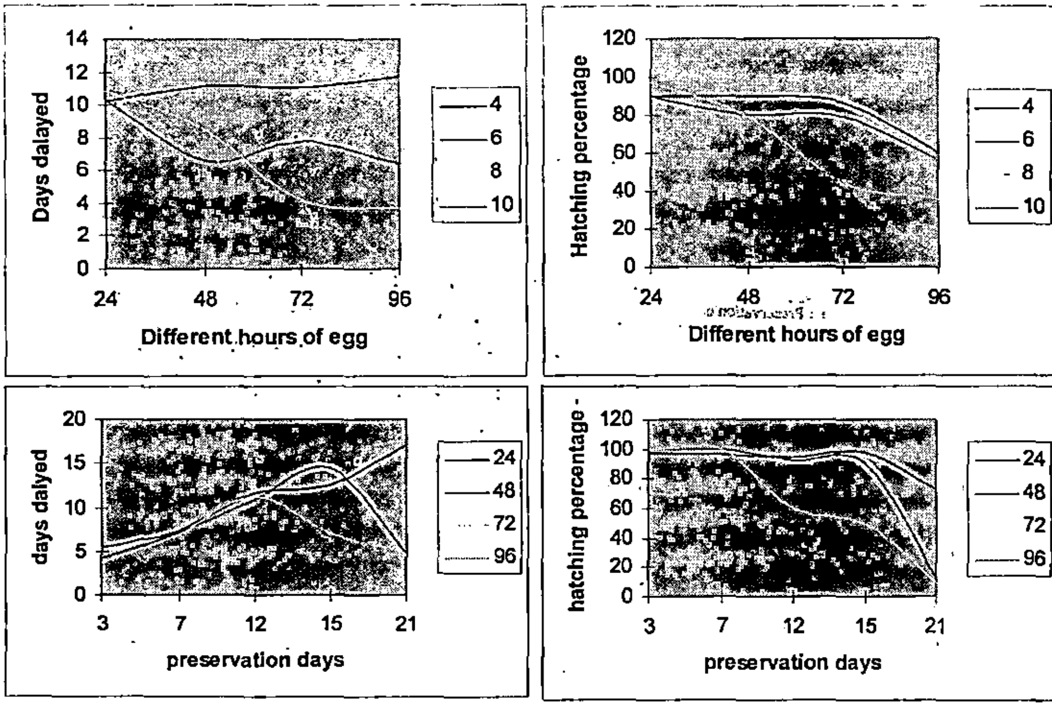

Fig. 1 : Effect of different age group of egg and preservation temperature on days delay of Hatching.
Figs. 2 : Effect of different age group of egg and preservation temperature on percentage of hatching.
Figs. 3 : Effect of different age group of egg and preservation period on days delay of Hatching.
Figs. 4 : Effect of different age group of egg and preservation period on percentage of hatching.

6°C and 96 hours 4°C showed better delay of egg hatching. Simultaneously delay was found higher with increased preservation days, highest being from 21 days, but hatching was only found for 24 hours laying at any temperature. In case of 48,72and 96 hours laying only at 4°C the eggs were hatched when preserved for 21 days. Highest delay for 19 days were obtained from 24 hours laying for 21 days preservation at 10°C followed non-significantly by 72 hours laying preserved for 21 days at 4°C (18.13 days), 48 hours and 96 hours laying for 21 days preservation at 4°C (18.06 days) and significantly by others. Days delay was minimum when eggs of 72 hours were preserved for 3 days at 10°C (3.03 day) having non-significant differences with layings of 48hours, 72 hours and 96 hours eggs for 3 days at any temperature (3.10-4.46 days).

Effect of laying, preservation period and preservation temperature on hatching percentage:

Hatching percentage, the ultimate reflection of cold preservation, was depicted in Table-3 and in the control batch hatching percentage is 82%.

Only the eggs of 24 hours laying for 21 days preservation at 8°C(98.93%)and 10°C(90.10%) showed better hatching percentage, but eggs of other hours were failed to show better hatching percentage

Table-1 : Effect of refrigeration at different temperature for different days on eggs of different days laying on incubation days.

°C / D*	24 hours Egg				48 hours Egg				72 hours Egg				96 hours Egg			
	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
3	11.96	12.16	12.30	13.20	11.36	11.00	11.46	11.33	10.96	11.06	10.46	10.03	10.5	10.40	10.10	0.00
7	14.03	14.13	14.36	15.06	14.46	13.96	14.50	14.03	14.10	14.63	14.03	13.60	16.03	13.53	13.53	0.00
12	18.00	18.10	18.50	20.10	18.13	17.03	18.96	17.46	19.43	20.10	17.50	15.96	20.06	16.96	16.06	0.00
15	18.96	18.96	20.10	20.20	22.10	18.96	25.16	20.06	21.03	21.03	0.00	0.00	22.16	19.03	0.00	0.00
21	22.96	23.30	24.10	26.10	25.06	0.00	0.00	0.00	25.13	0.00	0.00	0.00	25.06	0.00	0.00	0.00

CD at 5% : Egg laying x Preservation Day= 0.028; Egg laying x Temperature=0.024; Preservation day x temperature=0.028; Egg laying x Preservation temperature x Preservation day=0.512

Table-2 : Effect of refrigeration at different temperature for different days on eggs of different days laying on days delay of hatching..

°C / D*	First day laying				Second day laying				Third day laying				Fourth day laying			
	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
3	4.96	5.16	5.30	6.20	4.36	4.00	4.46	4.33	3.96	4.06	3.46	3.03	3.50	3.40	3.10	0.00
7	7.03	7.13	7.36	8.06	7.46	6.96	7.50	7.03	7.10	7.53	7.03	6.60	9.03	6.53	6.53	0.00
12	11.00	11.10	11.50	13.10	11.13	10.03	11.96	10.46	12.43	13.10	10.50	8.96	13.06	9.96	9.06	0.00
15	11.96	11.96	13.10	13.20	15.10	11.96	18.16	13.06	14.03	14.03	0.00	0.00	15.16	12.03	0.00	0.00
21	15.96	16.30	17.10	19.10	18.06	0.00	0.00	0.00	18.13	0.00	0.00	0.00	18.06	0.00	0.00	0.00

CD at 5% : Egg laying x Preservation Day= 0.118; Egg laying x Temperature=0.073; Preservation day x temperature=0.113; Egg laying x Preservation temperature x Preservation day=1.487

Table-3 : Effect of refrigeration at different temperature for different days on eggs of different days laying on percentage of hatching.

°C / D*	First day laying				Second day laying				Third day laying				Fourth day laying			
	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
3	99.46	99.50	99.50	90.13	99.90	99.56	98.33	99.66	98.80	99.63	99.60	99.83	99.56	99.56	80.16	0.00
7	99.30	99.30	99.56	89.30	99.73	99.63	99.60	99.76	98.10	99.73	99.72	99.46	80.16	80.36	80.06	0.00
12	99.66	99.53	90.26	88.90	99.83	99.73	99.70	69.70	98.50	99.56	20.00	20.06	80.03	79.36	20.03	0.00
15	99.70	99.70	99.70	89.96	99.36	99.83	99.43	59.90	98.66	98.73	0.00	0.00	19.93	19.46	0.00	0.00
21	50.30	50.10	98.93	90.10	49.80	0.00	0.00	0.00	39.93	0.00	0.00	0.00	20.13	0.00	0.00	0.00

CD at 5% : Egg laying x Preservation Day= 0.132; Egg laying x Temperature=0.065; Preservation day x temperature=0.092; Egg laying x Preservation temperature x Preservation day=11.510

preservation temperature on delay of hatching:

Control batch showed incubation period for 7 days and after 7 days eggs were hatched. So the delay of egg hatching was calculated by deducting these 7 days from the total incubation period of different treatments and results were furnished in Table-2.

Delay of hatching followed the same trend of incubation period i.e. for 24 hours laying at 10°C, for 48 hours 8°C, for 72 hours

Therefore the hatching of larvae has to be controlled, accelerated or postponded by artificial treatment under the refrigerated condition. In the life cycle the silkworm refrigeration is usually restored to all the four steps of development viz. egg (Yokoyama, 1962; Dutta *et al,* 1972; Tazima 1978), larva (Yokoyama, 1962; Tazima 1978) cocoon / pupa (Yokoyama, 1962; Tanaka, 1964; Kovalev, 1970), moth (Tazima 1978; Ayuzawa *et al,* 1972; Krishnaswami *et al,* 1978; Jolly, 1983; Ullal and Narasimhanna, 1978). But the cold storage is to be restricted to any one of the developmental stages of the silkworm for avoiding deleterious effects (Jolly, 1983). Hiratsuka (1975) opined that the eggs after oviposition can be preserved for 20 days with out affecting the rearing characteristics. Moreover, an increase in the chilling duration beyond 20 days results in a decrease in the hatching percentage of non-hibernating eggs (Furusawa *et al,* 1897; Narayanaswamy and Govindan, 1987). According to Chen Yuyin (2000) for silkworm the safety time for cold inhibition is 3-5 days and at 5°C with an intermediate temperature of 10-13°C for 2-3 hours. Any information about induction of delayed hatching of muga silkworm (*Antheraea assama* Westwood) through refrigeration is not available except Sahu *et al* (1998) according to whom 36 hours eggs can be induced for delayed hatching up to 36 days. Keeping this in view under consideration an attempt has been made to delay the hatching of Muga silkworm eggs of different age by cold temperature preservation at different temperatures for different days with an ultimate objective to find out the optimum condition of temperature stress on muga silkworm eggs to coincide the hatching with suitable environmental condition for commercial rearing.

MATERIALS AND METHODS

Seed cocoons were collected from Extension Centre, Regional Muga Research Station, Central Silk Board, Coochbehar, West Bengal. After moth emergence, coupling was done and egg laying of female were collected for low temperature preservation at 4, 6,8,10°C in BOD incubating first, second, third and fourth day laying for 3,7,12,15,21 days; simultaneously, a batch of eggs were allowed to hatch in normal condition to measure delayed hatching due to low temperature preservation. All data analysed statistically.

RESULT

Effect of laying, preservation period and preservation temperature on incubation period :

Incubation period increased with the increased duration of preservation period, highest being from 21 days of preservation. Regarding cold temperature preservation, 10°C was found best for the 24 hours eggs, 8°C for 48 hours, 6°C for 72 hours and 4°C for 96 hours egg. Highest incubation period was found on 24 hours egg at 10°C for 21 days, which was 26.10days and lowest being from 72 hours eggs at 10°C when preserved for 3 days, which was 10.03 days. However no egg was hatched in different treatments which were at 10°C on 96 hours eggs for all the preservation days, on 72 hours eggs for 15 and 21 days preservation and 48 hours eggs for 21 days, at 8°C 72 hours and 96 hours eggs for 15 and 21 days preservation, 48 hours eggs for 21 days preservation and at 6°C 48 hours, 72 hours and 96 hours eggs for 21 days preservation. No harmful effect was observed for 4°C preservation.(Table1)

Effect of laying, preservation period and

J. Exp. Zool. India Vol. 9, No. 1, pp. 249-254, 2006 *ISSN 0972-0030*

EFFECT OF LOW TEMPERATURE PRESERVATION ON DELAYED HATCHING OF EGG OF MUGA SILKWORM, *ANTHERAEA ASSAMA* WESTWOOD

Indrajit Biswas, Samiran Ghosh and Nilay Ray

Muga Research Lab, Department of Zoology, A.B.N.Seal College, Coochbehar-736101, India.

(Accepted 25 May 2005)

ABSTRACT - Among most successful animal groups in terms of species, insects are predominant one and estimates of total number of living species ranges from 10 to 30 million. Many factors must contribute to the profusion of insect species, but one key element is probably the developmental plan. Particular set of environmental stimuli such as temperature, photoperiod, humidity and nutrients play important roles for success of insect development. Developmental plan of insects can be manipulated purposefully by altering temperature. Insect eggs are one of the suitable stages for the study of the effect of environmental stimuli on the development of insect embryo. Keeping this in view under consideration, an attempt has been made to delay the hatching of eggs of muga silkworm (*Antheraea assam* Westwood), by cold temperature preservation with an objective to find out the maximum delay of hatching so that eggs can be supplied to the farmers as and when required. In the present investigation eggs were collected after 24, 48, 72 and 96 hours after laying and preserved at 4, 6,8,10°C for 3,7,12,15 and 21 days. Results show that when eggs are collected after different hours after laying and are preserved for 12 days at 6±1°C shows 100% hatching. Eggs collected 24 hours after laying and preserved at 10±1°C for 21 days shows delay of hatching for 19 days with satisfactory hatching percentage. From overall result it can be said that it is possible to induce delay of hatching without affecting hatching percentage using low temperature preservation as stress.

Key words : *Antheraea assama,* preservation, temperature, hatching.

INTRODUCTION

Among most successful animal group in terms of species insects are predominant one and estimates of total number of living species ranges from 10 to 30 million (Pearse *et al,* 1987). Many factors must contribute to the profusion of insect species, but one key element is probably the developmental plan. Particular set of environmental stimuli such as temperature, photoperiod, humidity and nutrients play important roles for success of insect development (Wei-hua Xua *et al,* 1995). Developmental plan of insects can be manipulated purposefully by altering temperature. Insect eggs are one of the suitable stages for the study of the effect of environmental stimuli on the development of insect embryo.

For the success of sericulture industry, proper supply of silkworm eggs (seed) is essential. The hatching period of eggs must coincide with the availability of suitable leaves as well as environmental conditions.

Corresponding author : N R