CENTRAL SILK BOARD

PPF 3585. Application of Growing Degree Days as a Model Driver for Developing Mulberry Yield Weather Model

RESEARCH PROJECT SUBMITTED BY

Dr. MONICA CHAUDHURI (nee Mukhopadhyay)

SCIENTIST-D, MORICULTURE -I

CENTRAL SERICULTURAL RESEARCH & TRAINING INSTITUTE,
CENTRAL SILK BOARD, MINISTRY OF TEXTILES: GOVT. OF INDIA,
BERHAMPORE - 742 101, WEST BENGAL, INDIA

PART I: GENERAL INFORMATION

1. **Name of the Institute / University /Organization submitting the Project Proposal:**

   Central Sericultural Research &Training Institute, Berhampore -742101, Murshidabad, West Bengal.

2. **Status of the Institute (s):** Research & Development of Mulberry sericulture

3. **Name (s) and designation(s) of the Executive Authority of the Institute/ University forwarding the application:**

   Dr. Kanika Trivedy, Director, Central Sericultural Research & Training Institute, Berhampore - 742101, Murshidabad, West Bengal.

4. **Project Title :** Application of Growing Degree Days as a model driver for developing mulberry yield weather model

5. **Category of the Project :** Applied

6. **Specific Area :** Mulberry crop management

7. **Duration :** 2 Years 3 months

8. **Total Cost :** Rs. 2,15,000.00

9. **Is the Project single Institutional or multi- institutional:** Single Institutional

10. **If the Project is multi-institutional, please furnish the Name, Designation and Address of the Project Coordinator:** N.A.

11a). Summary of the Project Proposal:

Mulberry *(Morus* sp.: Moraceae) figures as a very important commercial crop thriving extensively in tropical and temperate countries. Its foliage serves as the exclusive food for the silkworm, *Bombyx mori* L., a highly specialized phytophagous insect. Mulberry is perennial in nature and its assimilatory organs are harvested during various vegetative growth stages in commensuration with silkworm rearing.

Of late even very skilled rearers' assessment on the mulberry leaf availability prior to a crop schedule has started going wrong frequently and thus pre-determination of the size of rearing at the time of actual rearing eventually mismatches the leaf availability. Additional problem is arrangement of adequate and timely supply of silkworm parent seeds (P1) and even sometimes pre-seeds (P2) preceding commercial rearing which in turn encroaches upon the time allocation for research activities. Often congenial rearing environments are not met with instar-specific adequate harvestable mulberry leaves, thus various resources and efforts are wasted at different scales. These situations are occurring with greater recurrence under the spell of climate change and grossly erratic local weather. Drastic daily temperature pattern since last 5 years is one of the most unpredictable

attributes that affect plant and insects. The speed at which metabolism occurs in plants and insects is affected by temperature. This is because the enzymes that drive the reactions are sensitive to temperature for growth to occur and other life cycle processes to function.

Tracking temperature signals the very basis of leaf to silk conversion. A degree-day is a measure of the amount of heat that accumulates above a specified base temperature during a 24-hour period. Therefore a degree-day calendar renders technically much more help to the farmers in mulberry as well as rearing crop management. A pilot study to estimate the GDD requirement of mulberry foliage development and instar specific foliage yield as well as silkworm larval phenology towards cocoon yield was carried out for one year during June 2014 to May 2015. As per suggestions given by 42nd Research Advisory Committee (July, 2015) on the concluded study the present proposal is designed to carry forward the experiment.

Synchronization and judicious utilization of silkworm instar-specific mulberry leaf availability have been a long-standing problem of sericulture particularly in the eastern India. The present proposal contemplates to develop a mulberry yield weather model with the application of GDD as a model driver. The proposed study is a unique need-based initiative among various and continuous mulberry crop management strategies. A phenology-based environmental crop model comes handy in planning and carrying forth a crop even at the time of in-season variability with timely management intervention. Such models are essential component as the present paradigm shift decision of the GOOD GOVERNANCE drive of Ministry of Agriculture, Govt. of India, wherein thrust is on intervention and facilitating mode instead of package and norms mode for the farmers. In sericulture, though such governance has been initiated further studies are required for forecasting the mulberry foliage yield up to in-season level on temporal basis.

11b). Objective:

To prepare a model driven by growing degree days towards forecasting growth and yield of instar specific mulberry leaves under the spell of daily accumulated heat and basic weather variables.

PART II: PARTICULARS OF INVESTIGATORS

11.1.

a. **Name** : Dr. Monica Chaudhuri
b. **Date of birth** : 05.12.1957
c. **Sex** : Female
d. **Indicate whether Principal Investigator/ Co-investigator:** Principal Investigator
e. **Designation** & **Department** : Scientist - D, Moriculture Division-I
f. **Institute** / **University Address:**
Central Sericultural Research & Training Institute,
Berhampore- 742101, Murshidabad, West Bengal.

g. **2**. **Name** : Dr Kanika Trivedy
h. **Date of birth** : 15.07.1958
i. **Sex** : Female
j. **Indicate whether Principal Investigator/ Co-investigator:** Principal Investigator
k. **Designation** : Director
l. **Institute** / **University Address:**
Central Sericultural Research & Training Institute,
Berhampore- 742101, Murshidabad, West Bengal.

3.

a. **Name** :Dr. R. Mahesh
b. **Date of birth** : 25.05.1985
c. **Sex** :Male
d. **Indicate whether Principal Investigator/Co-investigator:**Co-Investigator[1]
m. **Designation** & **Department** :Scientist — B, Moriculture Division-I
e. **Institute** / **University Address:**
Central Sericultural Research & Training Institute, Berhampore-742101, Murshidabad, West Bengal.

4.

a. **Name** : Dr. G.R. Manjunatha
b. **Date of birth** : 11.08.1988
c. **Sex** : Male
d. **Indicate whether Principal Investigator/ Co-investigator:** Principal Investigator
e. **Designation** & **Department** : Scientist - D, Project Monitoring & Evaluation Division
f. **Institute** / **University Address:** Central Sericultural Research & Training

Institute, Berhampore- 742101, Murshidabad, West Bengal

5.

a. **Name:** Sri. Anil Pappachan
b. **Date of birth: 0**2.01.1989,
c. **Sex:** Male
d. **Indicate whether Principal Investigator / Co-investigator:** Co-Investigator 2
e. **Designation** & **Department:** Scientist — B, Mulberry Pathology
f. **Institute / University Address:**

Central Sericultural Research & Training Institute, Berhampore- 42101, Murshidabad, West Bengal.

13. No. of Projects being handled by each investigator at present:

Principal Investigator-1: One as PI

Principal Investigator-1

Co- Investigator 1: One as CI

Co- Investigator 2: One as CI

14. Proposed Research Fellows: NIL

PART III: TECHNICAL DETAILS OF PROJECT

15. Introduction: Growing degree days (GDD) is a weather-based indicator for assessing crop development. In the absence of extreme conditions such as drought or disease, plants and insects grow in a cumulative stepwise manner which is strongly influenced by the ambient temperature. The Growing Degree Days calculation allows producers to predict the plants' and insects' pace toward maturity. Daily growing degree day values are added together from the beginning of the season, providing an indication of the energy available for their growth. Growing degree day totals are used for comparing the progress of a growing season to the long-term average and are useful for estimating crop development stages and maturity dates.

Growing degrees (GDs) is defined as the mean daily temperature (average of daily maximum and minimum temperatures) above a certain threshold base temperature accumulated on a daily basis over a period of time. Negative values are treated as zeros and ignored. The base temperature varies among crops and the value is derived from the growth habits of each specific crop. The base temperature is that temperature below which plant growth is zero.

Unless stressed by other environmental factors like moisture, the development rate from emergence to maturity for many plants and insect-larvae depends upon the daily air temperature. Because many developmental events of plants and insects depend on the accumulation of specific quantities of heat, it is possible to predict when these events should occur during a growing season regardless of differences in temperatures from year to year.

While birds and mammals produce metabolic heat, enabling them to grow and develop in a range of ambient temperatures by burning food, ectothermic organisms rely on external sources of heat for their development. Because ectotherms require a certain combination of time and temperature, their development is a function of a given temperature and time over which it is acting. This time, called thermal or physiological time, is the basis of phenology models that use two values of thermal requirements: 1) lower developmental threshold (LDT), that is, the temperature at which development ceases (also called base developmental temperature); and 2) the sum of effective temperatures (SET), that is, day degrees (DD) above the LDT necessary for a completion of a developmental stage (Ludwig 1928). A heat accumulation of DD above LDT enables prediction of the time at which the development of individual stages of a species will be completed. In insects and mites, the thermal accumulation is usually modelled by daily maximum and minimum temperatures, assuming the sine curve as an approximation of the diurnal temperature curve (Baskerville and Emin 1969, Allen 1976).

Many species appear to be undergoing shifts in phenology as a result of climate change (Sparks & Carey, 1995; Crick et al., 1997; Menzel & Fabian, 1999; Roy & Sparks, 2000; Stefanescu et al., 2003), and phenological changes constitute a high proportion of all of the evidence that species are responding to climate change (Walther et al., 2002; IPCC, 2007). Thanks to comprehensive biological recording, butterflies have become a model group in detecting the impacts of climate change, including impacts on phenology (Sparks & Yates, 1997; Roy & Sparks, 2000; Forister & Shapiro, 2003; Stefanescu et al., 2003; Dell et al., 2005; Gordo & Sanz, 2006; Menzel et al., 2006). In insects, a variety of life history parameters may evolve in order to maximize fitness under the prevailing climate and the historic range of variability of that climate (Davidson, 1944; Lees, 1950; Manly, 1974; Visser, 2008). Insects respond to very specific cues which, over their evolutionary history, have helped them to stay in synchrony with important seasonal events, such as the bud burst of trees (van Asch et al.,2007). Temperature and day length (photoperiod) may

both be used as cues (Bale et al., 2002). Different species have evolved to use different cues, and because climate change affects temperature, GDD could lead to an adaptive response (Doi et al., 2008). A number of studies have used year-to-year variation in phenology (usually earliest emergence or mean emergence date) regressed on yearly climate to predict future changes (e.g., Roy & Sparks, 2000; Gordo & Sanz, 2006). As well as temporal changes, many species also show spatial variation in phenology (e.g., Zhou et al., 1995; Langvaten et al., 1996; White et al., 1997), but a given climate variable may have different effects over space and over time (Pollard, 1991; Rock et al., 1993; Thompson & Clark, 2006; Doi et al., 2008; Doi & Takahashi, 2008; Forkner et al., 2008). For example, the leafing date of Japanese trees varies less with the gradient of temperature over space than it does with changes in temperature over time at a single site (Doi & Takahashi, 2008).

The activity and development of plants is controlled by the temperature of the surrounding environment. It has long been recognized that growth could be measured indirectly by tracking temperature over time once the lower (baseline) and upper threshold temperatures for a particular insect were known. This would allow us to predict events in an insect's life cycle during the season by measuring growth in terms of temperature over time.

Climate has a profound effect on the distribution and abundance of insect pests, and the mathematical description of the climatic influence on pest development has been of considerable interest among entomologists. Additionally, as temperature exerts great influence among the climate variables, most of the models that describe insect development are temperature driven.

The first effort for a formal description of the relation between temperature and developmental rate was taken by botanists, to model the effect of temperature on plant growth and development. However, similar modeling procedures extended to most of the poikilothermic organisms, including insects as well. To date, the earliest experiment that related the velocity of insect development and heat, was made by Bonnet (1779) on the study of the reproduction rate of *Aphis evonymi*, F., while the major assumption and principles that have been brought out by these earlier works, constituted the basis for all future research. Nevertheless, since then, several theoretical and experimental works have been carried out and current progress in entomology, mathematics and computation offers new means in describing the relation of temperature to insect development.

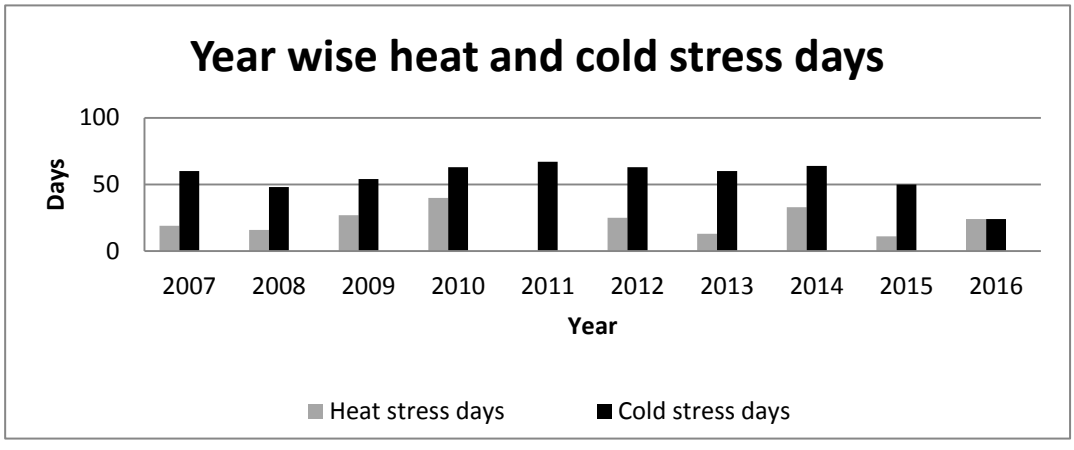
The success of sericulture industry depends upon several factors of which the impact of the environmental factors such as biotic and abiotic factors are of vital

importance. Among the abiotic factors, temperature plays a major role on growth and productivity of silkworm (Benchamin and Jolly,1986). It is also known that the late age silkworms prefer relatively lower temperature than young age and slight fluctuation of temperature during different stages of larval development was found to be more favourable for growth and development of larvae than constant temperature. There is ample literature stating that good quality cocoons are produced within a temperature range of 22-27°C and above these levels makes the cocoon quality poorer (Krishnaswami *et al*., 1973).

Mulberry *(Morus* sp.: Moraceae) figures as a very important commercial crop thriving extensively in tropical and temperate countries. Its foliage serves as the exclusive food for the silkworm, *Bombyx mori* L., a highly specialized phytophagous insect. Mulberry is perennial in nature and its assimilatory organs are harvested during various vegetative growth stages in commensuration with silkworm rearing.

Of late even very skilled rearers' assessment on the mulberry leaf availability prior to a crop schedule has started going wrong frequently and thus pre-determination of the size of rearing at the time of actual rearing eventually mismatches the leaf availability. Additional problem is arrangement of adequate and timely supply of parent silkworm seeds (P1) and even some times pre-seeds (P2) preceding commercial rearings which in turn encroaches upon the time allocation for research activities.

Often congenial rearing environments are not met with instar-specific adequate harvestable mulberry leaves. Or quality leaf abundance does not complement a predetermined rearing schedule, thus various resources and efforts are wasted at different scales. Mulberry withstands fairly wide range of temperature spanning 13°C to 37.7°C beyond which growth is arrested (Rangaswami et al., 1976, Sarkar et al, 2005; Ganga and Chetty, 2008). But it is observed through last decade that, the extent of duration of thermal stress regime is very erratic as can be seen from the following chart:



These situations are occurring even with higher frequencies under the spell of climate change and grossly erratic local weather. Drastic daily temperature pattern since last 10 years is one of the most unpredictable attributes that affects plants and its biotic environment.

Foliage harvest is a heavy stress on mulberry and Fukui (2000, 2001, 2005, and 2007) felt the necessity of estimating the state of the growth in order to obtain a stable yield and design silk worm rearing encompassing the effect of temperature and photoperiod on shoot elongation of mulberry. Because of yearly variations in weather, calendar dates were not a good basis for making management decisions regarding optimum resource utilization and reaping maximum possible harvest from a crop. Measuring the amount of heat accumulated over time provided a physiological time scale that is biologically more accurate than calendar days (Anonymous, 2003).

Unless stressed by other environmental factors like moisture coupled with, the developmental rate of foliage from emergence to maturity of mulberry depends upon the daily air temperature (Sugazawa, 1968; Suzuki and Kanaya; 1981).

Tracking development, growth and yield using thermal unit has taken momentum since 1990's in agricultural field crops and insects (Altman et al. 1995; Tripathy et al. 2004; Dubey et al.2006).

Since many developmental events of plants and insects depend on the accumulation of specific quantities of heat, it is possible to predict when these events should occur during a .growing season regardless of differences in temperatures from year to year (Miller et al. 2001).

Going by the basic concept of GDD, in mulberry the base temperature is experimentally determined as 13°C (Rangaswami *et al.,* 1976, Dutta, 2002; Sarkar *et al,* 2005; Ganga and Chetty, 2008). Growth is a complex process. It is defined as an irreversible increase in size of a living being or a part. Therefore, growth describes a quantitative change in an organism or a part thereof whereas development is defined as a qualitative change occurring in a plant, like initiation of leaves and shoot-elongation in mulberry,

Sarkar et al.(2005) pioneered the GDD study and deciphered relationship of growing degree days (GDD) with growth and yield of mulberry and emphasized the necessity of a mulberry crop calendar basing on GDD replacing the currently prevalent crop schedule based on calendar —day for proper resource management.

Intensive experimental studies on estimation of GDD requirement of both mulberry and silkworm were carried out by Chaudhuri and Khyriem (2012), Khyriem and Chaudhuri, Chaudhuri and Nirmal Kumar (2013), Chaudhuri et al. (2013) and Chaudhuri and Nirmal Kumar (2016).

A pilot study [P(S)008] to estimate the GDD requirement of mulberry foliage development and instar specific foliage yield as well as silkworm larval phenology towards cocoon yield was carried out by the principal investigator of the proposed project for one year during June 2014 to May 2015. The study revealed that

- Mulberry var. S1635 took 7-20 days to 85% sprouting of axillary buds with emerged leaves triggered by an accumulation of 119^0C-124^0C day.
- The peak average leaf yield/plant was realized when the GDD accumulation crosses 1100^0C day irrespective of calendar days lapsed after pruning.
- SK6, SK7 and SK6X SK7 was required 397 ^{0}C Day and 398 ^{0}C Day vis-à-vis mature larva weighing 3.248g, 2.970g and 3.070g respectively on average. MCon4and B Con4 required 378^0C to complete the larval duration weighing 2.681g and 3.013g at maturity.

A synthetic mulberry yield weather model was developed on historical data under the project PPF 3487 during 2012-13 by the aforementioned principal investigator. But real time adequate data generation is still due.

Even the pilot study for a year is not adequate for developing a new technique/ technology/product. Nevertheless the experiential results serve as a valuable cue to develop environmental calendar model for forcasting mulberry yield at temporal level.

15.1 DEFINITION OF THE PROBLEM: Synchronization and judicious utilization of silkworm instar-specific mulberry leaf availability and a viable cocoon yield forecasting system under the prevailing temperature thereof have been a long-standing problem of sericulture particularly in the eastern India. The present proposal contemplates to evolve a calendar depicting the time pattern linked to phenological events of mulberry under the influence of specific thermal requirement of mulberry towards yield optimization.

15.2 ORIGIN OF THE PROPOSAL / RATIONALE OF THE STUDY: Developmental phases of any biological entity are very much dependent on antecedent and prevalent temperature and the daily accumulation of heat. The amount of heat required to move a plant to the next phase of development remains constant from year to year owing to the genetic pre-disposition of the organisms. However, the actual amount of time in terms of calendar days can vary considerably from year to

year because of weather conditions. Tracking development, growth and yield using thermal unit has taken momentum since 1990's in agricultural field crops and insects. Each developmental stage of any organism has its own total heat requirement. Development and yield can be estimated by accumulating degree days between the high and low temperature thresholds throughout the life. Unless stressed by other environmental factors like water and biotic stress, the development rate from leaf emergence to harvest maturity in case of plants depends upon the accumulation of specific quantities of heat deciphered by daily air temperature and the respective base temperatures of mulberry and pests as 13°C and 10°C.

Since many developmental events of plants depend on the accumulation of specific quantities of heat, it is possible to predict when these events should occur during a growing season regardless of differences in temperatures from year to year.

The basic concept of Growing Degree Days is that plant development occurs when temperatures exceed a base temperature. In mulberry the base temperature was experimentally determined as 13°C. Using GDD calendar growth, development and produce of various horticultural and field crops are tracked for timely intervention with crop management devices and better resource utilization is ensured thereof. In case of insect pests GDD calendars are much more prevalent as handy crop protection tool for assured and projected prediction of harvests. Modeling the influence of biotic and abiotic factors on foliage yield up to in-season level would enhance the precision of the forecasting equation. The same rationale is utilized in the current project.

15.3. RELEVANCE TO THE CURRENT ISSUES and EXPECTED OUTCOME: The emerging thrust is on synchronizing the silkworm crop schedule with that of mulberry yield under the present erratic weather. This would avert the, loss of unutilized excess leaves at the end of commercial silkworm crops, necessitating additional silkworm crop to utilize excess quality mulberry leaves which otherwise would have gone on waste. The additional expenditure on account of labour cost towards leaf harvest, extra rearing, management of plantation and of rearing are the issues which can be addressed to with a very basic geo-spatio-temporal approach. The present approach, based on the concluded project (PPF 3487) and pilot study[P(S)008], takes care of fundamental and immediate environment in terms of basic weather regime, growth and development of mulberry and spatial thinking in terms of correlating all the components.

15.4 OBJECTIVE: To prepare a model driven by growing degree days towards forecasting growth and yield of instar specific mulberry leaves under the spell of

daily accumulated heat and basic weather variables.

16. REVIEW OF STATUS OF RESEARCH AND DEVELOPMENT ON THE SUBJECT

16.1 INTERNATIONAL STATUS: A global climate change has been experienced in all the regions of the earth over the last few decades. Effect of erratic climatic variability leads to unpredictable development, growth and yield of almost all field and plantation crops and beneficial insects which in turn takes a toll on the economic yield of the crops.

Bristow and Campbell, (1983) studied the relationship between incoming solar radiation and daily maximum and minimum temperature. This concept holds that the growth of a plant is dependent on the total amount of heat to which it is subjected to during its lifetime, accumulated as degree days.

Reid *et al.* (1990) showed that duration of leaf area growth in maize was inversely related to temperature. They proposed a generalized function relating duration of leaf area growth in maize to leaf number and temperature. Such an expression was the result of the difference between two functions relating the timing of leaf tip and leaf collar appearance to leaf number and temperature.

Klepper (1991) opined that a growing-degree day is a key tool to estimate the extent of developmental phases and resulting yield of the wheat plant.

Gordon and Bootsma analyzed the growth phases using growing degree-days for various agricultural crops in Atlantic Canada in 1993 emphasizing the inherent thermodynamism of the crops. Miller *et al.* (1993) reviewed the utility of GDD in tracking phenophases and yield of a number of field crops,

Plant development depends on temperature. Plants require a specific amount of heat to develop from one point of their life cycle to another such as from seeding to the four-leaf stage. People often use a calendar to predict plant development for management decisions. However, calendar days could be misleading, especially for early crop growth stages. GDD calendar has been used to estimate the growth and development of plants viz, wheat, barley oats, canary seeds, canola *(B.napus),* canola *(B.rapa),* mustard (B. juncea), mustard *(B. alba),* chick pea desi, lentil and pea, etc., during the growing season (Miller *et* a/,2001).

Fukui (2000), in his study to estimate the growth of mulberry by using shoot length as the growth parameter, developed a shoot elongation model which depicts the relationship between mulberry shoot elongation and environmental factors, i.e., temperature and photoperiod.

Womach (2005) described that the growth or development of trees is dependent on several environmental factors including temperature (heat), light and

humidity. Growing degree days are therefore used to predict the maturity stage of a plant and also even the life stages of an insect, for better management whether in terms of growth and development for harvesting the plant or for pests management.

16.2. NATIONAL STATUS: Rangaswami *et al.,* (1976) reported that the base temperature for mulberry is considered as 13°C, below which the growth of mulberry is zero. If the average temperature is equal to or less than the base temperature, no degree days are accumulated and the GDD for the particular day is considered as zero, hence accumulated GDD was used to find out its relationship with growth and yield.

In Indian context, thermal response of mulberry with regard to phasic development, growth and yield are very scanty. Mechanism and the results of the experimental investigations in other crops led the present comprehension. Prasad et.al. (1986) reported an extensive account on the phenology and seasonality in the tropical deciduous forest tree species which made their ecological niche in Bandipur forest.

Sarkar et. al. (2005) pioneered the investigation on thermal requirement of mulberry. For proper synchronization of mulberry growth with the silkworm rearing and better yield they drew a relationship between heat unit requirement by three mulberry varieties and emphasized the need to develop a GDD calendar for mulberry crop.

Kumar *et al* (2008) studied the time pattern related with the development of different phenophases in the plant as affected by the environmental factors. Based on Growing Degree days (GDD).and other related units they carried out their study for estimation of phenophases, growth and yield of soybean *(Glycine max* L.)

Bazgeer *et al* (2008), explained the phasic changes taking place due to the influence of both temperature and photoperiod. Sarma *et al* (2008) developed an agro-climatic model for the estimation of rice yield in Andhra Pradesh, using GDD and Integrated Normalized Difference Vegetation Index (NDVI).

Kalra et al., (2008) explicitly dealt with the effect of increasing temperature on yield of the predominating winter crops in northwest India and suggested the possible mitigation through development of thermo-plastic populations.

Ganesh (2010) stated that India is the mile stone in the horticulture map of the world being the second largest producer of fruit in world, contributing to 10 per cent of the total world production. Even with high production we are unable to a fetch good price in the markets. Up to 40 percent of fruit and vegetables go waste due to their perishable nature and the non availability of post harvest infrastructure and lack

of management. So in order to tackle these problems degree day calendars have started been used in recent years.

Tripathy et. al (2004) estimated quantitatively the heat-use efficiency of wheat genotypes under different crop growing environments. Pal and Murty (2010) also assessed the photo-thermal requirement of wheat

Investigation and evaluation on the same line using the above indices were carried out recently by Khyriem and Chaudhuri (2012). They presented an insight on the relationship of initiation and completion of important phenological processes and foliage yield of mulberry with growing degree days and photoperiod.

Chaudhuri (nee Mukhopadhyay) and Nirmal Kumar (2013) evaluated the Impact of weather on mulberry leaf yield using historical data. Chaudhuri and Khyriem (2013), Chaudhuri and Nirmalkumar (2013) quantified the antecedent photo-thermal energy utilization, in terms of GDD-mediated indices, triggering growth and realizing foliage yield of mulberry. A study on GDD required from hatching through each larval instar to cocooning of two popular silkworm breeds fed on two different mulberry varieties was carried out and estimated by Chaudhuri et.al. (2014) and Chaudhuri and Nirmal Kumar (2016).

16.3 IMPORTANCE OF THE PROPOSED PROJECT IN THE CONTEXT OF CURRENT STATUS:

The proposed project is a unique need-based initiative among various and continuous mulberry and silkworm crop management strategies towards precision sericulture. A phenology-based environmental model comes handy in planning and carrying forth a crop even at the time of in-season variability with timely management intervention. Such models are essential component as the present paradigm shift decision of the GOOD GOVERNANCE drive of Ministry of Agriculture, Govt. of India, wherein thrust is on intervention and facilitating mode instead of package and norms mode for the farmers. In sericulture, though such governance is yet to be implemented it can be worked out nonetheless as it was already initiated.

16.4 ANTICIPATED PRODUCTS, PROCESSES/ TECHNOLOGY PACKAGE INFORMATION OR OTHER OUTCOME FROM THE PROJECT AND THEIR

EXPECTED OUTCOME: The expected outcome of the proposed project is a mulberry yield-weather model basing on integrated environmental- cum phenological events which would help to develop ICT intervened downloadable Android and Apple application of growing degree days for free.

16.5 EXPERTISE AVAILABLE WITH PROPOSED INVESTIGATION GROUP / INSTITUTION ON THE SUBJECT OF THE PROJECT: Principal Investigator has been working on the subject since last five years, concluded a project on mulberry yield-weather model (synthetic) and a pilot study on estimation of GDD with respect to popular mulberry varieties. Additionally, the PI supervised six PGDS dissertations on the current subject. She is trained in Geo-Spatial and Temporal data management. Besides, all the three investigators are adept in running research projects/ programs.

16.6 LIST OF FIVE EXPERTS IN INDIA IN THE PROPOSED SUBJECT AREA:

Sl No	Name	Designation	Address

17. WORK PLAN

17.1. Methodology: The pilot study will be conducted with popular silkworm and mulberry variety, S1635 and as hereunder :

The time pattern related to the development of different phenophases in mulberry affected by the temperature will be recoded daily and used for computing degree days using the standard formula.

$$GDD = \Sigma\{[Tmax + Tmin]/2\text{-}Tb\}$$

Where,

Tmax = Maximum daily temperature in °C, `Tmin Minimum temperature in °C and

T b = Base temperature threshold (13^0 C and 13^0 C for silkworm and mulberry respectively)

- Biofixing of mulberry will be initiated a day after pruning and data recording will continue on dekadal basis
- Basic the weather variables will be recorded from AWS.

The data will be analyzed as per standard statistical procedure.

Observations on pest incidence

Pest	Observation to be taken from leaf	ETL
Thrips	4,5,6 and 7	20/leaf
Whitefly	Top 2, middle 2 and bottom 2	20/plant

Mealybug	% infestation = No of Tukra infested shoots ×100 / Total no of shoots	10%

Observations on disease incidence

Grade	% leaf lamina covered by the symptom
0	No infection
1	0-5% leaf lamina covered by the symptom
2	6-10% leaf lamina covered by the symptom
3	11-25% leaf lamina covered by the symptom
4	26-50% leaf lamina covered by the symptom
5	50% above leaf lamina covered by the symptom

Percent disease index (PDI) will be calculated according to FAO formula (1967)

$$\text{Percent disease index (PDI)} = \frac{\textbf{Sum of all disease ratings} \times 100}{\textbf{Total No. of leaves observed} \times \textbf{maximum grade} (5)}$$

Incidence of important mulberry disease like powdery mildew, rust, *Myrothecium* leaf spot, *Pseudocercospora* leaf spot and bacterial leaf spot will be recorded.

The incidence of pest and diseases will be recorded on temporal basis vis-a-vis growing degree days.

17.2. Organization of Work Elements

Sl.no	Name of the scientist	Time allocation	Work to be done
1	Dr. Monica. Chaudhuri, PI-1	30%	Bio-fixing, tracking mulberry phenology, extraction of temporal data sets, all spatio-temporal analysis
2.	Dr. Kanika. Trivedy, PI-2	20%	Popular vars. of silkworm rearing in environment chamber

3	Dr.R. Mahesh, CI-1	20%	Recording of mulberry (S 1635) phenology and yield vis-à-vis temporal weather
4	Dr. Dr. G. R. Manjunatha . CI-2	10%	Popular vars. of silkworm rearing in environment chamber and statistical analysis
5	Sri. Anil Pappachan, CI-3	20%	Recording of mulberry (S 1635) quantitative growth and yield, Recording observations on pest and diseases

17.3. Proprietary/ Patented items, if any, expected to be used for this Project: Established plantation of mulberry var. S1635 belonging to Agronomy/ Farm Management Section of CSR&TI, Berhampore

17.4. Suggested plan of action for utilization of the expected outcome from the project: The expected outcome of the project is a mulberry yield-weather model in the form of equation which can be used for decision support system towards precision sericulture and a freely downloadable GDD app compatible with Android and Apple application..

Sl. No.	**Milestone/ Activity**	**Expected Date of**		**Expected Outcome /visible/ measurable indicator**
		Starting	**Completion**	
Eo1	Pruning of mulberry, biofixing, phenological and temporal observation, extraction weather data	Oct , 2016	Sept, 2018	Estimates of GDD and impact of basic weather on mulberry crops
Eo2	Recording observations on pest and diseases	Oct, 2016	Sept. 2018	GDD estimates for pest and disease outbreak
Eo3	Brushing of popular silkworm varieties, biofixing, observation on growth development and yield in environ ment chamber	March, 2017	Sept, 2018/10 rearings of each popular silkworm var.	GDD estimates for silkworm crops

I.	Statistical analysis of observations	Oct, 2018	Dec, 2018	Mulberry foliage yield forecasting model

17.6. Program implementation Agency / Agencies:

Name of the Agency	Address of the Agency	Proposed Research Aspects	Proposed Amount (Rs. in Lakhs)	Cost sharing
Central Silk Board	Central Silk Board, BANGALORE — 560 068	Mulberry and Silkworm crop Management	2.15	100%

PART IV: **BUDGET PARTICULARS: (**Excluding salary of Scientists, Technical Staff and wages of Field workers/ Time scale field workers).

18. Budget (in Lakh Rupees): Rs. 2.15 lakhs (Single-institutional project)

A. **Non-Recurring** (e.g. equipments, accessories, etc. required/ available at the Institute). Nil

B. Recurring:

Particulars	1st Year	2st Year	3rd Year
A.Recurring	-	-	-
1.Remuneration /Salaries	-	-	-
2. Consumables (NPK, manure, PPM *etc.*)	15,000.00	15,000.00	-
3.Travel	20,000.00	20,000.00	-
4.0ther Costs (Consumable, rearing appliances, stationary, printer cartridge, maintenance cost of Enviroment Chamber *etc.*)	60,000.00	40,000.00	20,000.00,
B. Non-recurring	-	-	-
Permanent Equipment (chargeable battery operated Digital weighing balance and magnifying glass, Digital measuring tape *etc.*)	25,000.00	-	-
Sub Total	120,000.00	75,000.00	20,000.00
Total			**2,15,000.00**

B1. **Manpower:** 2 TAs from CSR&TI pool

Sl. No.	Position	Nos.	Consolidated Emoluments	1st year	2nd year	3rd year	Total
1	JRF/SRF/RA	-	-	-	-	-	-
2	HRA	-	-	-	-	-	-
3	CCA	-	-	-	-	-	-
Sub-total B1:				**-**	**-**	**-**	**-**

Other Items

PART V: EXISTING FACILITIES:

19. Available equipments and accessories to be utilized for the project:

Sl. No.	Name of the Equipment/ Accessories	Make Model	Funding Agency	
1.	Automatic Weather Station	B2		2011 (Installed by IMD, GOI.)
2.	Hot Air Oven		CSB	
3.	Computer with LASER printer		CSB	

5.	Environment Chamber	Environment Chamber with	CSB	Rs. 4,43,625.00

PART VI: REFERENCES

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Chaudhuri Monica(nee Mukhopadhyay) and Elfrida Kyriem (2012). Assessment of heat use efficiency of mulberry *(Morus* sp.) for foliage yield. Indian Biologist. 44(2): 51-54. ISSN 0302-7554.NAAS Rating: 2.2

Chaudhuri Monica (neeMukhopadhyay), S.S. Singh and B.B. Bindroo (2012). Estimation of impact of energy units on cocoon productivity of Muga silkworm *(Antheraea assamensis.* H) for sustainable semi-wild silkmoth culture. Proceedings of 7th International Conference on wild silkmoth and silk (Nov. 22-24, 2012). 0-006: 56-57.

Chaudhuri Monica (nee Mukhopadhyay), Elfrida Khyriem and B.B. Bindroo (2013) Estimation of photo-thermal requirements of mulberry for raising future population with plasticity. Book of Abstracts: 100th Ind. Sci. Cong. Agril. and Forestry Section. F-32:221-222

Chaudhuri Monica (nee Mukhopadhyay) and Elfrida Kyriem (2012). Assessment of heat use efficiency of mulberry (*Morus* sp.) for foliage yield. Indian Biologist. 44(2): 51-54. ISSN 0302-7554..NAAS Rating Impact factor: 2.2

Kyriem Elfrida and Monica Chaudhuri (neeMukhopadhyay) (2012). Use of phenology in ascertaining the thermal requirement of mulberry (*Morus sp*.). yield. Indian Biologist. 44(2): 51-54. ISSN 0302-7554..NAAS Rating Impact factor: 2.2

Chaudhuri Monica (nee Mukhopadhyay) and S. Nirmal Kumar (2013). Geospatial Thinking Initiative In Sericulture: Assessment of Real Time Photothermal Impact on Growth and Yield of Mulberry. Abstracted in proc. XXXIII Inter

Nat. Cong on Integrated Decentralized Planning: Geospatial Thinking, ICT and Good Governance. held at Regional Remote Sensing Centre, Jodhpur. Page 24

Chaudhuri Monica (nee Mukhopadhyay) and S. Nirmal Kumar (2013). Evaluation of Impact of Weather On Mulberry Leaf Yield. Indian Biologist. 46 (1): 23-29.

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Chaudhuri (nee Mukhopadhyay) Monica, Supen Subba, G.K. Chattopadhyay and S. Nirmal Kumar (2014). Preliminary estimation of thermal time requirement for growth of silkworm breeds. Indian Biologist. 46 (1):19-22. ISSN 0302-7554.

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Fukui K (2005). Modeling mulberry Shoot Elongation and leaf appearance in field condition. Plant Prod.Sci. 8: 115-121

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Gordon R. and A Bootsma(1993) Analyses of growing degree days for agriculture in Atlantic Canada. Climate Research. 3: 69-176

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Sarkar A, Rekha M. and Keshavacharyulu K. (2005). Relationship between heat unit requirement and growth and yield of Mulberry, *Morus indica* L. Int. J. Indust. Entomol. **10 (1):** 65-68.

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PART VII: BIODATA OF PROJECT CO-ORDINATOR / PRINCIPAL INVESTIGATOR / CO-INVESTIGATOR (S)

PRINCIPAL INVESTIGATOR-1

1. **Full Name (in Block letters):** Dr. MONICA CHAUDHURI (nee Mukhopadhyay)
2. **Designation:** Scientist-D
3. **Department/Institute/University Address for communication:**
   Central Sericultural Research & Training Institute : Agronomy, Central Sericultural Research & Training Institute, Institute, Berhampore — 742 101, Dist. Murshidabad, West Bengal
4. **Date of birth :** 05.12.1957
5. **Sex :** Female

6. Education (Post Graduation onwards & Professional Career):

Name of the University	Degree Passed	Year of Passing	Subject taken with specialization	Class/ Division
Calcutta University	M.Sc (Ag)	1980	Agriculture (Genetics & Plant Breeding)	1st
Gauhati University	PhD	2003	Genetic study of some life cycle traits of certain phenotypes of muga silkworm reared on different host plants.	

Memberships/fellowship: Indian science Congress Association, UN Group of Knowledge Management for Development

Patents: (Not required for in-house personnel)

Publications (Number only):

Books: One chapter

Research Papers / Reports: 23 full papers, 20 abstracts

General articles: 6

List of important publications whose contents can be used in the proposed area of work:

1. Monica Chaudhuri (nee Mukhopadhyay) and Elfrida Kyriem (2012). Assessment of heat use efficiency of mulberry *(Morus* sp.) for foliage yield. Indian Biologist. 44(2): 51-54. ISSN 0302-7554.
2. Monica Chaudhuri (nee Mukhopadhyay), S. Roy Chowdhury, Jalaja S. Kumar and B.B.Bindroo (2012). Retrospective analysis of historical weather variables and mulberry *(Morus alba* L) foliage yield. Proceedings of National Seminar (May 11-12, 2012, Umium) on Plant Genetic

Research for eastern and North-eastern India, organized by Indian Society of Genetics and Plant Breeding. PS-II :8: p76

3. Monica Chaudhuri (neeMukhopadhyay), S.S. Singh and B.B. Bindroo (2012). Estimation of impact of energy units on cocoon productivity of Muga silkworm *(Antheraea assamensis.* H) for sustainable semi-wild silkmoth culture. Proceedings of 7th International Conference on wild silkmoth and silk (Nov. 22-24, 2012). 0-006: 56-57
4. Monica Chaudhuri (neeMukhopadhyay), Elfrida Kyriem and B.B. Bindroo (2013). Estimation of photo-thermal requirement of mulberry for raising future population with plasticity. Proceedings of 100th Indian Science Congress (Jan. 3-7, 2013, Kolkata; Section of Agriculture and Forestry). F-32: 221-222.
5. Monica Chaudhuri(nee Mukhopadhyay) and S. Nirmal Kumar (2013). Geospatial Thinking Initiative In Sericulture : Assessment of Real Time Photothermal Impact on Growth and Yield of Mulberry. Abstracted in proc. XXXIII Inter Nat. Cong on Integrated Decentralized Planning: Geospatial Thinking, ICT and Good Governance. held at Regional Remote Sensing Centre, Jodhpur. Page 24
6. Monica Chaudhuri (nee Mukhopadhyay) and S. Nirmal Kumar (2013). Evaluation of Impact of Weather On Mulberry Leaf Yield. Indian Biologist. 46 (1): 23-29.
7. Monica Chaudhuri (nee Mukhopadhyay) and S. Nirmal Kumar (2013). Geospatial Thinking Initiative In Sericulture: assessment of real time photothermal impact on growth and yield of mulberry. Indian Cartographer. Vol. XXXIII: 72-79.
8. Chaudhuri (nee Mukhopadhyay) Monica, Supen Subba, G.K. Chattopadhyay and S. Nirmal Kumar (2014). Preliminary estimation of thermal time requirement for growth of silkworm breeds. Indian Biologist. 46 (1):19-22. ISSN 0302-7554.
9. Monica Chaudhuri (nee Mukhopadhyay) and S. Nirmal Kumar (2016)application of growing degree days for sericulture management. In the proceedings of 103rd Indian science congress. pp. 73
10. Khyriem Elfrida and Monica Chaudhuri (neeMukhopadhyay) (2012). Use of phenology in ascertaining the thermal requirement of mulberry *(Morus sp.).* yield. Indian Biologist. 44(2): 51-54. ISSN 0302-7554.

PRINCIPAL INVESTIGATOR-2

1. Full Name (In Block letters) : Dr. KANIKA TRIVEDY
2. Designation : Director
3. Department/Institute/University : Central Sericultural Research & Training Institute, Berhampore - 742 101
4. Date of birth : 15th July 1958
5. Sex : Female
6. Education qualifications : M.Sc., Ph. D

Academic records

Ph.D Thesis title :
Histological studies on the metamorphic changes in the neurosecretory cells of the brain during pupal period in a lepidopteron, *Prodenia litura* Fabr.

Education qualifications

Examination	subjects	University	Year of passing	% of marks	Class/ Division
Higher Secondary	General subjects	Board of secondary Education, Bhopal, MP	1974	64%	I div
B.Sc.	Zoology, Botany and Chemistry	Jiwaji University Gwalior, MP	1977	65%	I div (IX Rank)
M.Sc.	Zoology with Entomology specialization	Jiwaji University Gwalior, MP	1979	67%	I div IV Rank Received two years National Scholarship on the basis of B.Sc. Result
Ph. D.	Insect endocrinology -	Jiwaji University Gwalior, MP	1989	-	Received Individual CSIR, Junior Research Fellowship for three years (1980-1982)

Awards:

1. International: WIPO Gold medal and certificate for "Best woman Inventor of the year 2004" by World Intellectual Property Organization, Geneva on 11th May 2005 at New Delhi.
2. National : "Technology day award 2004" bears individual shield, certificates and Rs. 1 lakh jointly for meritorious invention of SAMPOORNA on 30th June 2004 at New Delhi
3. Institute: Award on "Annual day celebration 2008" from Director, CSR&TI, Mysore, for the outstanding contribution in the field of sericulture research.
4. Awarded 1st Prize Rs. 1500/- and Certificate for oral presentation for a Hindi paper , Ranchi held on 26-27th April 2011.
5. Best poster Awarded to the poster Green" silk: Dye Chemistry to Dyeability by On "National Science day (28th February 2012)" at NCL, Pune

Patents granted:

1. Process of extraction of ecdysteroid used for uniform and advanced maturity of silkworm (sampoorna) (Patent no. 193857, dated 14.06.2001) granted on 6th Dec 2005 (Filed IPR no. 475/Mas/2001 dated 14.6.2001).
2. A silkworm feed and a process for preparation thereof (Patent no. 218430, dated 3.02.99) granted on 1st April 2008 (Filed IPR no. 133/Mas/99 dated 3.2.99)
3. A semi-synthetic diet for rearing young instar tropical tasar silkworm, *Antheraea mylitta* (Patent no. 240259, dated 12.06.2007) granted on 30th April 2010 (Fi ledno.IPR/4.13.19.1/06096/2008) 1214/CHE/2007, dt. 12.6.2007

4. Universal diet for young age silkworm- “SERINUTRID” Patent no. 247304 dated 10.9.2007 granted on 31.3.11 (filed vide patent no.IPR/ 4.3.21/ 06097/2007) 2020/CHE/2007, dt. 16.9.2007\

Publications

1	International Indexed Journal	**20**
2	International Proceeding	**03**
3	National Indexed Journal	**38**
4	National Proceeding	**20**
5	Blog	**01**
6	Book/Chapter/Theme paper/Compiled	**07**
7	Popular Article	**24**
8	Abstract in International symposium/Seminar/Confrences	**06**
9	Abstract in National symposium/Seminar/Confrences	**40**

CO- INVESTIGATOR - 1

1. **Full Name (In Block letters)** **:** Dr. R. Mahesh
2. **Designation** : Scientist-B
3. **Department/Institute/University Address for communication** :

   Agro-Physio-Farm mangement,

   Central Sericultural Research & Training Institute, ,

   Berhampore - 742 101, Dist. Murshidabad, West Bengal
4. **Date of birth** : 25.05.1985
5. **Sex** : Male

6. Education (Post Graduation onwards & Professional Career):

Name of the University	**Degree Passed**	**Year of Passing**	**Subject taken with specialization**	**Class/ Division**
Tamil Nadu Agricultural University	M.Sc (Ag)	2009	Agriculture (Agronomy)	1st
Tamil Nadu Agricultural University	Ph.D (Ag)	2016	Agriculture (Agronomy)	

Publications (Number only): Nine

CO- INVESTIGATOR – 2

Name	**Dr. G. R. Manjunatha** Scientist-B
Date of Birth	11th May 1988

Educational Qualification

Sl. No	**Institute Place**	**Degree Awarded**	**Year**	**Award/Prize/Certificate**
1	University of Agricultural Sciences Dharwad, Karnataka	M.Sc (Agri) in Agril. Statistics	2011	**1st Rank** **Dissertation topic**: Use of statistical tools in organic farming practices in northern zones of Karnataka
2	Bhidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal	Ph. D (Agri) in Agril. Statistics	2016	**Thesis topic**: Combinatorial aspects & optimality properties of generalized neighbour designs in circular block **Supervisor**: Prof. A. Majumder, Dept. of Agril. Statistics, BCKV, Mohanpur

Academic Accolades

- ✓ I received, University of Agricultural Sciences **Gold Medal** for having secured the highest grade point average among the M.Sc (Agri) in Agril. Statistics graduates during 2010-11.
- ✓ I received, *Dr. G. K. Veeresh, Former Vice-Chancellor, UAS, Bangalore* ***Gold Medal*** for having obtained First Rank among the M.Sc (Agri) graduates who

have worked on Organic Farming related problems during the year 2010-11.

- ✓ Qualified for **ICAR-NET 2013**
- ✓ Awarded '**INSPIRE Fellowship'**, Department of Science & Technology, Government of India for pursuing of full time Ph.D degree
- ✓ Qualified for '**ICAR-SRF 2014'**, from ICAR, Government of India.
- ✓ Upgraded for '**INSPIRE Fellowship from JRF to SRF**' assessed by Prof. Rahul Mukherjee, IIM, Kolkata.

Awards related to publications

- ❖ **DR. ANAMITRA SAHA PRIZE AWARD** for one of the **Best Article** published in ***Indian Journal of Agricultural Economics*** during the year **2013**.
- ❖ DR. G. R. SETH MEMORIAL YOUNG SCIENTIST **AWARD 2014** for the paper entitled "Generalized Efficiency Balanced Designs in Circular Blocks with Correlated observations" authored by S. G. Patil, A. Majumder and **G. R. Manjunatha** at ICAR-IASRI, New Delhi during ***68th annual conference of Indian Society of Agricultural Statistics***.
- ❖ DR. G. R. SETH MEMORIAL YOUNG SCIENTIST **APPRECIATION CERTIFICATE 2015** for the paper entitled "Generalised Neighbour Designs in Circular Blocks with Group-Divisible Association Scheme for Correlated Observations" authored by **G. R. Manjunatha**, A. Majumder and S. G. Patil at University of Kota, Rajasthan during ***69th annual conference of Indian Society of Agricultural Statistics***.

Publications (numbers only):

- ❖ Research papers : 20
- ❖ Abstracts: 15
- ❖ Popular article in Hindi: 01

Publications relevant to the project proposal

- Majumder, A., **Manjunatha, G. R**. and Patil, S. G. 2015. Efficient Circular Neighbour Balanced BIB Designs with minimum number of blocks for Correlated observations. ***International Journal of Agril. and Statistical Science****,* 11(2). 449-458.
- **Manjunatha**, **G. R.,** Kiran Kumar, R. P. and Chandrakanth, M. G. 2014. Optimal Stocking Pattern of Chemical Fertilizers: An Application of Waiting Time Model. ***Indian Journal of Marketing****, 44(10),* 34-40. [NR-**3.89**]

CO- INVESTIGATOR – 3

1. **Full Name (in Block letters)** : Mr. ANIL PAPPACHAN
2. **Designation** : Scientist-B
3. **Department/Institute/University Address for communication:**

   Agro-Physio-Farm Management,

   Central Sericultural Research & Training Institute, Institute,

   Berhampore -742 101, Dist. Murshidabad, West Bengal
4. **Date of birth** : 02.01.1989
5. **Sex** : Male
6. **Education (Post Graduation onwards & Professional Career):**

Name of the University	Degree Passed	Year of Passing	Subject taken with specialization	Class/ Division

ANGRAU, Hyderabad	M.Sc (Ag)	2013	Agriculture (Plant Pathology)	1st

Publications (Number only):

Research Papers / Reports: 6 full papers, 1 abstract