Journal of
Entomology

ISSN 1812-5670

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Journal of Entomology

ISSN 1812-5670
DOI: 10.3923/je.2017.176.185

Research Article

Estimation of Jute Leaf Chlorophyll Content and Dynamics of Semilooper in Relation to Nitrogen Topdressing

[1,2]Abdul Sadat and [2]Kaushik Chakraborty

[1]Department of Sericulture, Raiganj University, Raiganj, 733134 West Bengal, India
[2]Department of Zoology, University of Gour Banga, Mokdumpur, Malda, 732103 West Bengal, India

Abstract

Background and Objective: Jute is a bio-degradable fibre crop with high value in agrarian India economy and deserves agricultural attention because it can minimize use of non-degradable plastic products. A portable chlorophyll estimating tool (SPAD 502 meter) is useful for instant chlorophyll measurement both in field and laboratory conditions and may be ideal for determining nitrogen (N) requirement, since the laboratory method for determining chlorophyll content from leaf tissue is time consuming, laborious and destructive. This study was designed with objectives to evaluate relationship between chlorophyll content of jute leaf with nitrogen topdressing as conventionally adopted by the farmers and dynamics of jute semilooper incidence at Uttar Dinajpur, West Bengal. **Materials and Methods:** To achieve this objective, periodic occurrence of pest incidence and leaf chlorophyll content was assessed in relation to N topdressing and accordingly their correlation were statistically analysed by one-way ANOVA and KyPlot. **Results:** In 2017 semilooper population was initiated at about 18th standard meteorological weeks (SMW) and gradually increases upto 30th SMW. Linear regression and simple correlation analyses evicted a clear significant increase in leaf chlorophyll content and incidence of *Anomis sabulifera* having a consonance with the amount of field nitrogen fertilizer application. **Conclusion:** This study will supposed to specify the time-fitted field application of N fertilizer in field condition to achieve higher fibre yield keeping semilooper population at lowest level which will minimize field application of both fertilizers and pesticides leading to eco-friendly sustainable production system.

Key words: *Corchorus olitorius*, SPAD reading, chlorophyll, nitrogen topdressing, Jute semilooper (*Anomis sabolifera*)

Citation: Abdul Sadat and Kaushik Chakraborty, 2017. Estimation of jute leaf chlorophyll content and dynamics of semilooper in relation to nitrogen topdressing. J. Entomol., 14: 176-185.

Corresponding Author: Abdul Sadat, Department of Sericulture, Raiganj University, Raiganj, 733134 West Bengal, India Tel: +919932341504

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

As a major fibre crop jute (*Corchorus olitorius*) shares a pivotal place in Indian agrarian economy. From time immemorial, jute leaf is used for food, for packing materials and also for traditional medicine and hence attains special concern[1]. West Bengal within India shares about 80% national jute production[2]. To maximizes jute production judicious and time-fitted application of N fertilizer as a prime macro-nutrient is required[3].

Further, increase of concerns to global environmental issues and anticipation to the ill effect of non-degradable plastic products[4], adoption of jute as eco-friendly product is prioritised under modern IPM practices[5]. The objective of 'eco-friendly field management' under precision farming is conceptualized by a system approach to know the total system of agriculture towards a low input, high efficiency and sustainable agriculture. It includes a crop management strategy that employs detailed, region-specific information to well balance 'production inputs' and aims to maximize the 'production output'.

Chlorophyll is the major photosynthetic pigment. The prime roles of this pigment are to absorb and to react with visible light in photosynthesis[6]. Chlorophyll content per unit leaf area reflects plant photosynthetic capacity and accordingly growth status of the crop plants[7]. Leaf chlorophyll concentration ensures leaf greenness. Leaf greenness is primarily affected by the N status of the plant following field N application. Further, change of morpho-anatomical structure of leaf following plant growth corroborates with the alteration of leaf chlorophyll concentration and photosynthetic activity[8].

The complex behaviour of N in the soil has several important implications for managing N for optimum jute production and for determining availability of soil N. Jute has the greatest need for N starting about 20-30 days after emergence. To increase the efficiency of N utilization, N fertilizer to be applied in phases.

Since the chlorophyll meter has the potential to detect N deficiencies, it also shows promise as a tool for improving N management[9-11]. Thus, specific adjustments and measurement protocols are required for each species, apparatus[12,13] and growth conditions[14].

Jute semilooper (*Anomis sabolifera*) is one of the notorious and destructive herbivorous insect pests to jute plant rendering up to 50% crop loss[15]. Attack to jute plant depends on leaf nutrient content especially N. Higher the greenness higher would be the insect pest incidence due to organo-lepticques[8]. Proper management of field N will in turn control the leaf green colour and accordingly check insect pest menace[6].

Absorbance-based chlorophyll measurement has become accepted mostly in small-scale eco-physiological experiments[16]. The chlorophyll meter or SPAD meter (soil plant analysis development) is a simple, portable diagnostic tool that measures the greenness or relative chlorophyll content of leaves[17]. Chlorophyll meter readings are given in SPAD value. A definite strong linear relationship exists between SPAD value and leaf nitrogen concentration[18]. The SPAD value helps to assess crop N status and additional N requirement in relation to plant health[3]. This study was designed with objectives to evaluate relationship between chlorophyll content of jute leaf with nitrogen topdressing as conventionally adopted by the farmers and dynamics of jute semilooper incidence at Uttar Dinajpur, West Bengal.

MATERIALS AND METHODS

Area of observation:

- **Location:** Three jute growing areas having an average elevation between 0.5 and 0.7 m above sea level of the District Uttar Dinajpur, West Bengal, India were primarily considered. The study sites were Raiganj (25°36'46" N, 88°07'28" E), Hemtabad (25°41'00" N, 88°13'00" E) and Kaliyaganj (25°63'44" N, 88°32'66" E). All of the selected places were aerially separated by about 15 km
- **Agro-climatic conditions:** All of the selected places were prone to flood. Mean annual rainfall ranges from 1200-1600 mm with the dry season lasting from October-November to April-May. Temperature was 24.6-38.2°C and RH was 38.2-96.4% during the period of experimentation
- **Pedological characteristics:** Soil of the experimental fields showed pH value 6.8 and EC value 0.28 mmhs cm^{-1}. N, P_2O_5 and K_2O contents were 280, 26 and 265 kg ha^{-1}, respectively

Experimental design: The experiment was conducted in selected jute fields during April-August of the year 2017 with 3 replications. Before sowing N, P_2O_5 and K_2O at the rate of 20 kg ha^{-1} were applied as basal application to the field. The jute seeds were sown in a row spacing of 25 cm in small plots of 4×4 m with a gap of 1.0 m between each plot. At completely grown condition, plant to plant distance was maintained at 6-8 cm apart after thinning. Nitrogen (N) fertilizer treatment done by farmers as use of urea with a cumulative rate of 0, 12, 24, 36, 48 and 60 kg ha^{-1} at an interval of about 20 days from the day of sowing.

Estimation of leaf chlorophyll by SPAD 502 chlorophyll meter:

- **Structure of SPAD chlorophyll meter:** The SPAD chlorophyll meter provides instantaneous and non-destructive readings on a plant based on the quantification of light intensity. The SPAD meter is a simple, portable diagnostic tool that measures the greenness or the relative chlorophyll concentration of leaves against SPAD reading[19]
- **Working principle:** The SPAD has a flexible shaft and another rigid shaft and the leaves are held in between these two shafts through the pressure of the flexible shaft in the direction of the rigid shaft. The flexible shaft has two diodes that emit light beams at 650 nm (red) and 940 nm (near infrared), through the leaf tissue and two detectors, located on the rigid shaft, measure light transmittance. The light transmitted, dependent on the tone of green in the leaf[20]. Then the light signals converts into electrical signals, amplified and again converted into digital signals. This signals used by microprocessor to calculate the SPAD value which are shown in display monitor. The obtained values of chlorophyll in SPAD value are proportionate to the amount of chlorophyll present in leaf because the wavelength used in SPAD chlorophyll meter were based on two absorbance peaks of chlorophyll *in vitro*[21]
- **Sampling protocol:** Leaf samples were collected randomly on 20 days after Transplanting (DAT). Fully expanded leaf of 10 plants in 3 plots from each of the three selected area was used for SPAD measurement. The SPAD readings was in triplicates taking (i) On one side of the midrib of each single leaf blade, (ii) Midway between the leaf base and (iii) Tip of the leaf and then collected data was then averaged

Estimation on jute semilooper population: Incidence of pest was monitored in three different sites from each experimental plot. Incidence of the semilooper on the crop was recorded as the percentage of plant infestation. For this purpose, 1 m^2 area in each site were observed for pest attack in 3 replication and then percentage of plant infestation was calculated based on total number of plants m^{-2}.

Data analysis: Statistical analysis of observed data were done by following one way analysis of variance model, through KyPlot version 2.0 beta 15 (32 bit) using 5% level of significance[22]. The relation of leaf chlorophyll content and insect pest incidence with used nitrogen fertilizer was compared by using simple linear correlation analysis[22].

RESULTS AND DISCUSSION

Study of the relation between chlorophyll content (measured in SPAD 502 chlorophyll meters) of jute leaf and percent incidence of jute semilooper with nitrogen topdressing by the jute farmers in jute crop field was assessed in pre kharif to kharif period by randomized block design during the year 2017 at three different sites from three different administrative blocks of the district Uttar Dinajpur, West Bengal, namely, Raiganj, Hemtabad and Kaliyaganj, respectively. The result is delineated below.

Observation on the impact of nitrogen topdressing on leaf chlorophyll content: Farmers generally had shown jute at about 15SMW.N was applied to the jute field in 5 phases. About 20 kg ha^{-1} was initially applied as basal dose. After emergence of twig most of the farmers in the three administrative blocks has usually applied nitrogen fertilizer with successively at the rate of 0, 12, 24, 36, 48 and 60 kg ha^{-1} at about SMW 15, 18, 21, 24, 27 and 30, respectively.

Leaf chlorophyll content corroborates with the dose of applied field N. In most of cases higher the doses of N, higher is the leaf chlorophyll content. Table 1 shows that the chlorophyll reading of jute leaves was increased with increasing dose of applied N top dressing recorded at Raiganj, Hemtabad and Kaliyaganj as, from 26.6-46.4, 26-45.8 and 25.9-46, respectively in SPAD unit.

Deliberated chlorophyll reading of jute leaves in SPAD (502) chlorophyll meter were significantly correlated ($p \leq 0.05$) with N fertilizer top dressing applied by the jute farmers of three different blocks of Uttar Dinajpur District. Linear models were adequate in explaining the relationship with the correlation analysis (r-value) 0.9273*, 0.9251* and 0.8706* for Raiganj, Hemtabad and Kaliaganj, respectively (Fig. 1).

Findings of present study are unswerving with findings of other researchers[23-26,12]. They had depicted that SPAD 502 meters give differing prediction responses for different plant species. Therefore, the calibration line prepared in this study is species specific. Thus any attempt to illustrate calibration lines it is important task to developed regression analysis model for each specific plant species and cultivar[27]. In present study linear regression analysis and correlation analysis (r-value) showed a well fitted and significant relation among reading of SPAD 502 chlorophyll meter and nitrogen topdressing (Fig. 1).

Table 1: Leaf chlorophyll content of jute leaves and pest infestation in three blocks of Uttar Dinajpur district (2017)

SMW	Nitrogen fertilizer used (kg ha^{-1})	Chlorophyll reading of jute leaves in SPAD (502) chlorophyll meter			Extent of infestation (percentage of leaf) of jute semilooper		
		Raiganj	Hemtabad	Kaliyaganj	Raiganj	Hemtabad	Kaliyaganj
15	0	00.00±0.00	00.00±0.00	00.00±0.00	00.00±0.00	00.00±0.00	00.00±0.00
18	12	26.60±1.07	26.00±0.43	25.96±0.77	02.14±0.45	02.56±0.43	01.74±0.72
21	24	31.10±0.94	30.76±0.40	30.93±0.55	15.45±0.26	16.76±0.40	16.24±0.35
24	36	35.63±0.78	35.76±0.60	35.73±0.50	34.64±0.73	36.32±0.60	35.34±0.46
27	48	40.63±2.05	39.26±1.06	40.13±0.60	42.36±0.42	43.62±1.06	42.34±0.72
30	60	46.43±0.80	45.83±0.30	46.00±0.52	44.56±0.72	45.33±0.30	44.39±0.64

Data were reported as Mean±SD of three replica

Observation on the incidence of jute semilooper in relation to N top dressing and leaf chlorophyll content: Grossly, semilooper larvae population was first appear at about month of May. The number then increased slowly in the early crop growing season and population growth accelerates in mature vegetative stage in the month of June. High population was maintained up to mid of July-August. The population then infest jute crop in a fluctuating manner until crop harvested.

Table 1 shows that during 2017, semilooper infestation started during 2nd week of May (SMW 18) with a lower plant injury level which gradually increases up to1st week of August (SMW 30) with an elevated dose of nitrogen. Observation in all the three blocks showed an increase in pest incidence with a little variation. Being a foliage feeder, this insect remained active till harvest of the crop in fluctuating manner.

Correlation studies were made to establish the relationship between pests' incidence and N top dressing. Weekly mean of these factors were correlated with the percentage of plant and leaf infestation and numbers of pest recorded during the corresponding week. Correlation of the semiloopers' incidence with the leaf chlorophyll content during the year 2017 shown in Fig. 2. The results revealed that incidence of semilooper (*A. sabulifera*) was shown significant ($p \leq 0.001$) positive correlation with N top-dressing.

Linear regression and simple correlation analysis (r value) were also well fitted to evicted positive relation within pests' incidence and leaf chlorophyll content (Fig. 3). This relation showed positive significant values at Raiganj ($p \leq 0.05$), Hemtabad ($p \leq 0.0001$) and Kaliyaganj ($p \leq 0.05$).

Chlorophyll accounted for more than 98% of gross primary production variation in maize and other crops[28]. The chlorophyll content of leaf has been suggested as the community property and has proportional relation to predict productivity. The use of non-destructive methods of chlorophyll measurement provides reliable and effective means of plant analysis in a wide range of biological context. For that reason, which organ of the plant (normally the leaf), which part of the organ, which position of the plant the organ will be located, which season, among other aspects, must be predefined for performance of the SPAD readings and preferentially, they should be obtained in experiments with plants grown in soils with different textures, organic matter content and availability of mineral N, which may be created by the application of increasing doses of mineral nitrogen fertilizer in the soil. Changes in leaf chlorophyll content often have been regarded as a relatively late mechanism of photosynthetic adaptation[29]. Chlorophyll content of leaves is a useful indicator of both

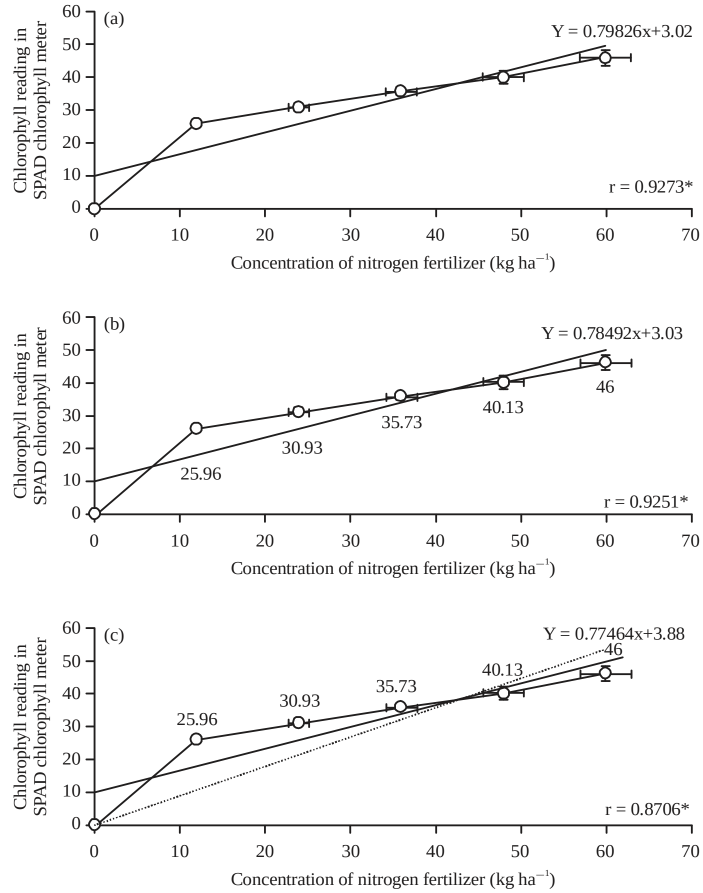

Fig. 1(a-c): Relation between chlorophyll value in SPAD unit and nitrogen topdressing by the farmers in Raiganj, Hemtabad and Kaliyaganj, U/D, West Bengal, 2017. values are Mean±SD

Significant at: *p≤0.05

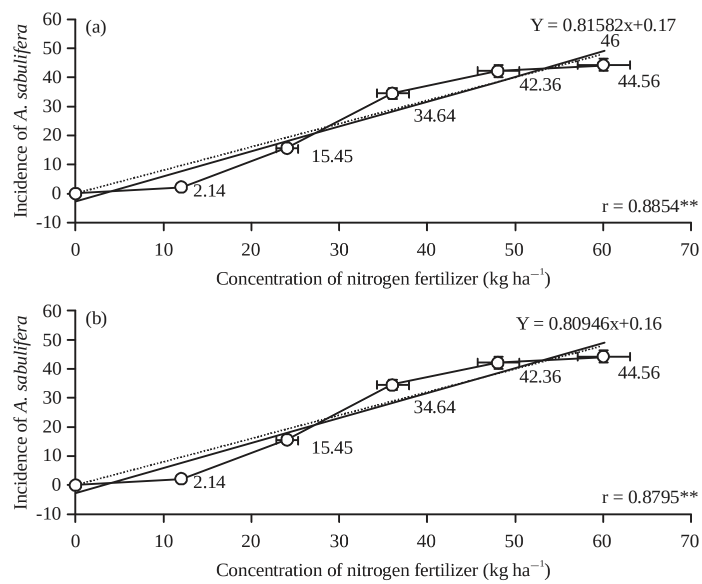

Fig. 2(a-c): Continue

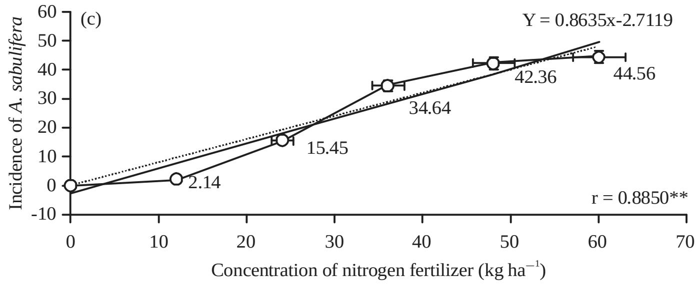

Fig. 2(a-c): Relation between pest (*A. sabulifera*) attack and nitrogen topdressing in Raiganj, Hemtabad and Kaliyaganj, U/D, West Bengal, 2017. values are Mean±SD
Significant at: **p≤0.001

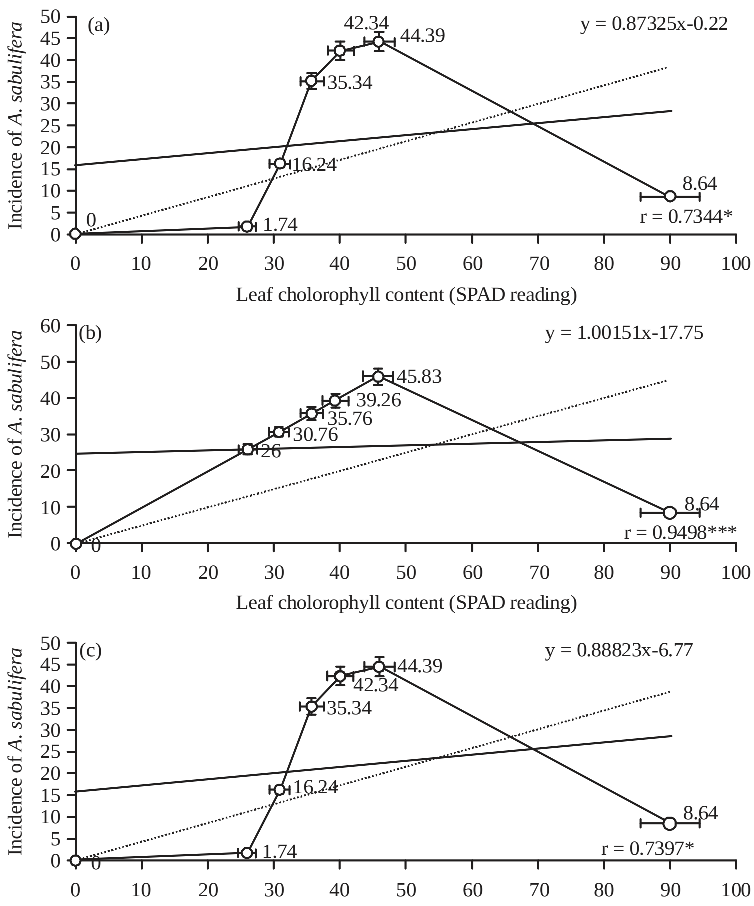

Fig. 3(a-c): Relation between pest (*A. sabulifera*) attack and chlorophyll value in SPAD unit in Raiganj, Hemtabad and Kaliyaganj, U/D, West Bengal, 2017. values are Mean±SD
Significant at: *p≤0.05, ***p≤0.0001

potential photosynthetic productivity and general plant vigour[30,31]. In addition, changes in the amount of chlorophyll may be a part of adaptive responses[32] specifically to the phytophagous pests.

For that reason, in recent years in some fruit-bearing species like apple trees[33], peach trees[20], pear trees[34] and also the grapevine[35] the total N content in the leaves has been estimated through the use of non-destructive methods like those that use portable equipment, among them the SPAD-502. This result does not corroborate those obtained by Crusciol *et al*.[26], where the highest levels of available soil N and greater consumption of this element did not make the plants produce chlorophyll than they needed. Therefore, the portable meter SPAD-502 proves to be ineffective to the luxury consumption of N, because the device measures the intensity of green coloration and nitrogen that is not embedded in the chlorophyll molecules do not reflect the variation of the staining intensity[21]. Lack of response fact of nitrogen is due, probably the dynamics in the soil and rain lack during the application of the element in question. Nitrogen critical levels for various species were established after years of research, due to peculiarities. However as no literature was found in the appropriate content in the crambe leaves, was used as a comparison the critical level (leaf analysis) for the castor bean and sunflower[25]. In this context the N critical level determination for crambe crop, can be important goal of future study work and subsequently also possible the development of another survey to determine the needs of N, apply as from the use of chlorophyll. Crusciol *et al*.[26] and Godoy[21], reported that the using possibility the chlorophyll in the indication of nitrogen deficiency in bean and maize, respectively. Argenta *et al*.[36], in an experiment correlating the N content of corn leaf chlorophyll and reading, go further, concluding that this method can be well spent, depending on the developmental crop development stage, because in the early stages the values of the readings do not are very accurate.

In present study linear correlations of SPAD chlorophyll meter reading with nitrogen topdressing were well significant but there was little difference in jute leaves collected from different blocks though all the model plants belongs to same species *Corchorus olitorius* (Fig. 1). There are a number of probable reasons for the variation in relationship with in SPAD reading and nitrogen topdressing.

An active photosynthesis due to adequate solar radiation takes place during pre-kharif and kharif period in West Bengal. These on to go photosynthesizing leaves may harbour pools of nitrogen which are not component of chlorophyll, such as free NO_3 in vacuoles waiting to be transported to their destinations[37] may be affect the reading. Another source of error is sampling difficulties. Contrasting the chlorophyll estimation from leaf tissue by chemical method, the portion of leaf surfaces used for SPAD 502 measurements did not correspond exactly to the leaf disc from which other elements can be measured. On the other hand different portion of the same leaf may show different SPAD value. Therefore, authors need to be careful to take multiple reading from same leaf and then average it[38]. Loh *et al*.[12] also reported that, verifying leaf thickness affects the precision of SPAD 502 meter reading and thus increasing variability. Therefore, difference in leaf thickness may be another possible explanation for little variation in relation between SPAD 502 chlorophyll meter reading and nitrogen topdressing.

According to Loh *et al*.[12], Da Silva *et al*.[19] and Liu *et al*.[39] in spite of these limitations SPAD 502 chlorophyll meter is a potentially useful instrument for rapid non-destructive crop management. In collaboration with soil test, SPAD 502 is a quit useful tool for detection of plant status in field condition. Silva *et al*.[40], advocated for more systemic sampling method including standardizing leaf position of chlorophyll reading and sampling time to minimize prediction variability.

Non-destructive methods have therefore been developed and inexpensive optical chlorophyll meters, such as the SPAD-502 (Konica Minolta, Osaka, Japan) are frequently used. Indeed, SPAD value depends not only on chlorophyll content but also on other aspects of leaf optics, which may be influenced by various environmental and biological factors. The establishment of reference curves relating SPAD-unit and total foliar chlorophyll under controlled environmental conditions is therefore a high priority. Timely and non-destructive leaf N status detection could allow real time decision and improvement in N management. Chlorophyll meter utilization to evaluate plant N status at real time is suitable for precision agriculture and canopy greenness might serve as a useful diagnostic tool to assess plant N demand.

Matching agreement between crop demand and supply is one of the prerequisites for efficient N use. Approaches based on N contents in leaves have been used to increase N fertilizer use efficiency. Since SPAD readings are closely related to leaf N content, the SPAD meter can be used to monitor the N status of rice and thereby to adjust the rate of N fertilization in order to increase N use efficiency. In this study also analyses of data collected on 80DAT was used to determine SPAD data can be used to predict leaf N amount and future crop N need. SPAD readings taken on 80DAT had a good relationship to leaf total N concentration, therefore, assessment of crop N status is good to be done based on SPAD reading if we decide to take correct fertilizer amount to achieve higher yield.

Present study showed a significant ($p \leq 0.001$) upsurge of insect pest population following field N application. As leaf N is proportionately related to field N application, judicious N management can pamper plant growth. Leaf N corroborates to the greenness of the leaf. Sawicka and Michalek[41] reported that higher the greenness higher would be the insect pest incidence due to organo-leptic ques. Proper management of field N will in turn control the leaf green colour and accordingly check insect pest menace[6].

Finally, the result suggests that, SPAD 502 chlorophyll meter can provide a quantitative measure of the leaf chlorophyll content which is related to the use of N fertilizer and pest attack. Further study on different verities of jute can help to construct an idea of judicious nitrogen fertilizer management for maximum fibre yield keeping pest incidence below economic threshold level for promoting sustainable jute production.

CONCLUSION AND FUTURE RECOMMENDATION

It was concluded that present study evicted a clear relation between dynamics of *A. Sabulifera*, jute leaf chlorophyll content and nitrogen topdressing by the farmers of Raiganj, Hemtabad and Kaliyaganj, U/D, West Bengal, 2017. Profusion of pest population changes with changing amount of leaf chlorophyll and concentration of applied N fertilizer throughout the jute growing season.

The information may be utilized for planning the appropriate time fitted insect pest management strategies and judicious fertilizer use for sustainable agriculture. Stipulated data in the present study may provide foundation to other researchers for developing their research model and understanding the pest-chlorophyll-fertilizer relation.

SIGNIFICANCE STATEMENTS

This study reveals the influence of nitrogen (N) top dressing on chlorophyll content of jute leaf and occurrence of lepidopteran jute insect pest, *Anomis sabulifera* which are major threat to jute cultivation. This study can be beneficial for judicious nitrogen fertilizer application and time fitted IPM management to minimize insect pest menace and to maximize fiber production for promoting sustainable jute production.This study will help the researcher to uncover the critical areas of insect pest occurrence and also need based N fertilizer application in relation and pest seasonality in the upper Gangatic plains. Thus a new management protocol on jute insect pest management strategy may be extrapolated.

REFERENCES

1. Islam, M.M., 2013. Biochemistry, medicinal and food values of jute (*Corchorus capsularis* L. and *C. olitorius* L.) leaf: A review. Int. J. Enhanced Res. Sci. Technol. Eng., 2: 35-44.
2. Chapke, R., C.R. Biswas, S.K. Jha and S.K. Das, 2006. Technology evaluation through frontline demonstrations and its impact. Central Research Institute for Jute and Allied Fibres, Bulletin No. 03, pp: 19.
3. Da Silva, T.R.B., R.F. Lavagnolli and A. Nolla, 2011. Zinc and phosphorus fertilization of crambe (*Crambe abyssinica* Hoechst). J. Food Agric. Environ., 9: 264-267.
4. Hester, R.E. and R.M. Harrison, 2011. Marine Pollution and Human Health. Royal Society of Chemistry, UK., ISBN-10: 184973240X, pp: 84-85.
5. Hammer, J., M.H.S. Kraak and J.R. Parsons, 2012. Plastics in the marine environment: The dark side of a modern gift. Rev. Environ. Contam. Toxicol., 220: 1-44.
6. Taiz, L. and E. Zeiger, 2010. Plant Physiology. 5th Edn., Sinauer Associates, Sunderland, Massachusetts, pp: 604-605.
7. Bowyer, J.R. and R.C. Leegood, 1997. Photosynthesis. In: Plant Biochemistry, Dey, P.M. and J.B. Harbome (Eds.)., Academic Press, London, pp: 49-110.
8. Hawkins, T.S., E.S. Gardiner and G.S. Comer, 2009. Modeling the relationship between extractable chlorophyll and SPAD-502 readings for endangered plant species research. J. Nat. Conserv., 17: 123-127.
9. Peterson, T.A., T.M. Blackmer, D.D. Francis and J.S. Scheppers, 1993. Using a chlorophyll meter to improve N management: A web guide in soil resource management: D-13 fertility. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln, New York, USA.
10. Smeal, D. and H. Zhang, 1994. Chlorophyll meter evaluation for nitrogen management in corn. Commun. Soil Sci. Plant Anal., 25: 1495-1503.
11. Balasubramanian, V., A.C. Morales, R.T. Cruz, M. Thiyagarajan, R. Nagarajan, M. Babu and L.H. Hai, 2000. Adaptation of the chlorophyll meter (SPAD) technology for real-time N management in rice: A review. Int. Rice Res. Inst., 5: 25-26.
12. Loh, F.C.W., J.C. Grabosky and N.L. Bassuk, 2002. Using the SPAD 502 meter to assess chlorophyll and nitrogen content of Benjamin Fig and Cottonwood leaves. HortTechnology, 12: 682-686.
13. Uddling, J., J. Gelang-Alfredsson, K. Piikki and H. Pleijel, 2007. Evaluating the relationship between leaf chlorophyll concentration and SPAD-502 chlorophyll meter readings. Photosynth. Res., 91: 37-46.

14. Marenco, R.A., S.A. Antezana-Vera and H.C.S. Nascimento, 2009. Relationship between specific leaf area, leaf thickness, leaf water content and SPAD-502 readings in six Amazonian tree species. Photosynthetica, 47: 184-190.
15. Sadat, A. and K. Chakraborty, 2015. Feeding behaviour and dynamics of lepidopteran insect pests of jute in response to the plant phenology and phyto-nutrients: An overview. Asian J. Biochem. Pharm. Res., 5: 162-177.
16. Neufeld, H.S., A.H. Chappelka, G.L. Somers, K.O. Burkey, A.W. Davison and P.L. Finkelstein, 2006. Visible foliar injury caused by ozone alters the relationship between SPAD meter readings and chlorophyll concentrations in cutleaf coneflower. Photosynth. Res., 87: 281-286.
17. Chung, S.O., J.H. Sung, K.A. Sudduth, S.T. Drummond and B.K. Hyun, 2000. Spatial variability of yield, chlorophyll content and soil properties in a Korean rice paddy field. Proceedings of the 5th International Conference on Precision Agriculture, Bloomington, Minnesota, USA., July 16-19, 2000, American Society of Agronomy, pp: 1-14.
18. Rostami, M., A.R. Koocheki, M.N. Mahallati and M. Kafi, 2008. Evaluation of chlorophyll meter (SPAD) data for prediction of nitrogen status in corn (*Zea mays* L.). Am.-Eurasian J. Agric. Environ. Sci., 3: 79-85.
19. Da Silva, T.R.B., A.C. de Souza Reis and C.D. de Goes Maciel, 2012. Relationship between chlorophyll meter readings and total N in crambe leaves as affected by nitrogen topdressing. Ind. Crops Prod., 39: 135-138.
20. Thomidis, T. and C. Tsipouridis, 2005. Influence of rootstocks, pH, iron supply (in nutrient solutions) and *Agrobacterium radiobacter* on chlorophyll and iron concentration in leaves of a peach variety. J. Plant Nutr., 28: 1833-1842.
21. Godoy, L.J.G., 2002. [Management of nitrogen top dressing on maize (*Zea mays* L.) in sandy soil based on the relative chlorophyll content]. Mater Thesis, Universida de Estadual Paulista, Botucatu.
22. Sadat, A. and K. Chakraborty, 2017. Studies on incidence of jute semilooper in relation to weather of Uttar Dinajpur, India. J. Entomol., 14: 96-103.
23. Marquard, R.D. and J.L. Tipton, 1987. Relationship between extractable chlorophyll and an *in situ* method to estimate leaf greenness. HortScience, 22: 13-27.
24. Schaper, H. and E.K. Chacko, 1991. Relation between extractable chlorophyll and portable chlorophyll meter readings in leaves of eight tropical and subtropical fruit-tree species. J. Plant Physiol., 138: 674-677.
25. Malavolta, E., G.C. Vitti and S.A. Oliviera, 1997. Availiacao do Estado Nutricional das Planta: Principios e Aplicacoes. 2nd Edn., Associacao Brasileira para Pesquisa da Potassa e do Fosfato, Piracicaba, Pages: 319.
26. Crusciol, C.A.C., M.E. Andreotti, E. Furlani Jr. and J. Nakagawa, 2001. Leaves of nutrients, chlorophyll concentration and grain yield of common bean as a function of nitrogen seeding or coverage. Rev. Agric., 76: 101-114.
27. Santos, J.I., F. Rogerio, B.T. Gouveia, A.C.S. Reis, R.A. Migliavacca, A. Nolla and T.R.B. Silva, 2011. Potassium management in the crambe development on sandstone region. Proceedings of the Congresso Brasileiro de Ciencia do Solo, July 31-August 5, 2011, Uberlandia, Brazil.
28. Gitelson, A.A. and M.N. Merzlyak, 1997. Remote estimation of chlorophyll content in higher plant leaves. Int. J. Remote Sens., 18: 2691-2697.
29. Wiesler, F., M. Bauer, M. Kamh, T. Engels and S. Reusch, 2002. The crop as indicator for sidedress nitrogen demand in sugar beet production-limitations and perspectives. J. Plant Nutr. Soil Sci., 165: 93-99.
30. Alonso, M., M.J. Rozados, J.A. Vega, P. Perez-Gorostiaga, P. Cuinas, M.T. Fonturbel and C. Fernandes, 2002. Biochemical responses of *Pinus pinaster* trees to fire-induced trunk girdling and crown scorch: Secondary metabolites and pigments as needle chemical indicators. J. Chem. Ecol., 28: 687-700.
31. Zarco-Tejada, P.J., J.R. Miller, G.H. Mohammed, T.L. Noland and P.H. Sampson, 2002. Vegetation stress detection through chlorophyll a+b estimation and uorescencee ects on hyperspectral imagery. J. Environ. Qual., 31: 1433-1441.
32. Morales, F., A. Abadia, J. Abadia, G. Montserrat and E. Gil-Pelegrin, 2002. Trichomes and photosynthetic pigment composition changes: Responses of *Quercus ilex* subsp. *ballota* (Desf.) Samp. and *Quercus coccifera* L. to Mediterranean stress conditions. Trees, 16: 504-510.
33. Neilsen, D., E.J. Hogue, G.H. Neilsen and P. Parchomchuk, 1995. Using SPAD-502 values to assess the nitrogen status of apple trees. HortScience, 30: 508-512.
34. Peryea, F.J. and R. Kammereck, 1997. Use of Minolta SPAD-502 chlorophyll meter to quantify the effectiveness of mid-summer trunk injection of iron on chlorotic pear trees. J. Plant Nutr., 20: 1457-1463.
35. Rupp, D. and L. Trankle, 1995. A non-destructive measurement method for chlorophyll in grapevines. Mitteilungen Klosterneuburg, Rebe und Wein, Obstbau und Fruechteverwertung, 45: 139-142.
36. Argenta, G., P.R.F. Silva, C.G. Bortolini, E.L. Forsthofer and M.L. Strieder, 2001. Relationship of reading with the chlorophyll content of chlorophyll and extractable nitrogen in maize leaf. Rev. Bras. Fisiol. Veg., 13: 158-167.
37. Marschner, H., 1995. Mineral Nutrition of Higher Plants. 2nd Edn., Academic Press Ltd., London, UK., ISBN-13: 978-0124735439, Pages: 889.

38. Loh, F.C.W., 2000. Nutrient and chlorophyll status of ficus and popular grown in CU-strutural soil. MS Thesis, Cornell University, Ithaca, New York.
39. Liu, Z.A., J.P. Yang and Z.C. Yang, 2012. Using a chlorophyll meter to estimate tea leaf chlorophyll and nitrogen contents. J. Soil Sci. Plant Nutr., 12: 339-348.
40. Silva, T.R.B., V.E. Leite, A.R.B. Silva and L.H. Viana, 2007. Nitrogen topdressing in the culture of the castor been in no-till. Pesq. Agropec. Bras., 42: 1357-1359.
41. Sawicka, B. and W. Michalek, 2005. Evaluation and productivity of *Helianthus tuberosus* L. in the conditions of central-east Poland. Electron. J. Pol. Agric. Univ., Vol. 8.