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Effect on biology of jute indigo caterpillar, *Spodoptera litura* (Fabricius) under five different constant temperatures

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Abstract
Effect of six constant temperatures *viz*., 18±1 °C, 21±1 °C, 24±1 °C, 27±1 °C, 30±1 °C and 33±1 °C on growth, development and survival of *Spodoptera litura* (Fabricius). Development rate of egg, larvae, pupae and adult gradually increased with increase in temperature, while the total development period decreased. The total life span of the insect decreased from 64.19±2.86 days at 18±1 °C to 27.18±1.64 days at 33±1 °C. The egg hatchability, larvae reaching 4th instar, total pupation and adult emergence were maximum at 27±1 °C and it decreased with the increase or decrease in the temperature. Developmental thresholds were determined to be 11.93, 10.68, 9.54 and 10.98 for egg, larvae, pupae and adults respectively with corresponding thermal constants being 34.48, 344.82, 163.93 and 107.52 degree days. Thermal constant to complete a generation was found to be 650.70 DD. These estimated thermal thresholds and degree days could be used to predict the *S. litura* activity in the field for their effective management through pest forecasting and time of insecticide application.

Keywords: *Spodoptera litura*, Biology, thermal constant, development threshold, jute

1. Introduction
Jute, *Corchorus olitorius* (Malvaceae) is an important fibre crop next to cotton which is grown mostly in India and other south East Asian countries [1]. The biotic stress particularly the insect pests adversely affect the yield and quality of fibres. Many insect pests are associated right from germination to harvest of jute crop. Among them *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae), known as indigo caterpillar remain active during the early plant establishment and growth stage. It is a highly polyphagous and destructive insect pest, damaging economically important crops like tobacco (*Nicotiana tabacum* L.), castor (*Ricinus communis* L.), cotton (*Gossypium* sp. L.), soybean (*Glycine max* L.) and groundnut (*Arachis hypogea* L.) including jute crop throughout tropical and temperate Asia, Australasia and the Pacific Islands [2,3]. It sporadically assumes destructive nature in the early sown jute crop where its activity is confined to seedling or young jute plants. Occurrence is more prevalent in jute seed crop, active throughout the crop growth stages.
The young larvae after hatching web either margin of the same leaf or two top leaves, shelter inside and start voraciously feeding the green matters [1]. The damage is noticed even from distance especially border plants. Within these webs the young larvae live gregariously only for two or three days and thereafter they separate and spread out. The feeding activity of grown up larva is generally confined to morning hours and late evening. They are quite large patches of foliage are quickly stripped and top plants are webbed together. The leaves are skeletonized; the older caterpillars often devour the entire lamina and March-April is the peak period of its infestation [4]. The pest has very high fecundity and the caterpillars are destructive defoliators and damage the leaves. The extent of damage may go up to 20% fibre yield loss [5] and the yield loss varies with the intensity of infestation, host plant quality and weather conditions. Timely management is very important as delay may even lead to complete defoliation of crop if remains unchecked. Being a polyphagous pest, the population builds up and consequent damage in jute is largely dependent on other parallel and overlapping hosts grown under climatic conditions. Insects are physiologically sensitive to temperature, have short life cycle and great mobility, and their developmental rate and geographical distribution are therefore highly responsive to changes in temperature [6].

During the last few years the pest status of indigo caterpillar in terms of regularity of occurrence and the extent of damage in jute have enhanced. With a changing climate, there is the potential for *S. litura* to become an increasingly severe pest in certain regions due to increased habitat suitability [7]. Reproductive biology of an insect may be affected both positively and negatively. Temperature has strong influence on the development, reproduction and survival of insect pests and as a result it is likely that these organisms will be affected by any change in climate [8]. Being poikilothermic organism, the developmental rate in insects is highly contingent on external temperature conditions. Hence, temperature is generally considered the single most significant environmental factor influencing behavior, distribution, development, survival and reproduction in insects [8]. Knowledge on the temperature-dependent population and growth potential of insect pests is highly imperative for understanding their population dynamics and implementing agro-ecoregion specific pest control strategies, especially in the context of predicted global climate change [9]. The vast majority of studies that infer the effects of temperature on developmental biology of *S. litura* have been undertaken under only one constant temperature in laboratory [10,11,12,13,14]. The present study was aimed to know the effect of five different constant temperatures on the biology of *S. litura* on jute as its host plant.

2. Materials and Methods

The experiment was conducted at Crop Protection Division of ICAR-Central Research Institute for Jute and Allied Fibres (ICAR-CRIJAF), Barrackpore Kolkata, India (22°45'N, 88°26'E) during February to May, 2016 as per the methodology [15].

2.1 Insect culture: The newly hatched gregarious larval masses of *S. litura* were collected from unsprayed jute crop from the research farm of ICAR-CRIJAF. Further, the larvae were maintained on fresh leaves of jute in rearing containers (30cm ht. × 20cm dia.) at 27±1 ^{0}C temperature, 70-80% relative humidity (RH) and 12L:12D condition for development and multiplication to get a homogeneous population. Freshly emerged moths were released in oviposition cage for egg laying on 40 days old jute plants. After 7 days, the lower leaf surface containing egg masses were collected. The F_1 eggs of the laboratory reared *S. litura* were used in the experiments.

2.2 Temperature dependent development of *Spodoptera litura*: Ten F_1 eggs were placed in Petri plates containing insecticide free jute leaves of uniform sizes (as food) which were further placed in BOD incubator (Biological Oxygen Demand) at different temperatures *viz.,* 18 ^{0}C±1, 21 ^{0}C±1, 24±1 ^{0}C, 27±1 ^{0}C, 30±1 ^{0}C and 33±1 ^{0}C and 70-80% RH and 12L:12D condition. These temperatures were selected for precisely determining favorable temperature range and the entire life cycle in the range of at 18±1 to 33±1 ^{0}C. These required temperatures were set in the incubators with five replications for each temperature using ten F_1 eggs for each replication. The development of different stages of the test insect was observed. Observations on the egg hatchability, larval mortality, larval, pupal duration and adult emergence were recorded at 24 hour interval. Based on the data generated, the incubation period (days), mortality of larvae during various life stages (%), larval duration on different instars (days), total larval duration (days), pupal duration (days) and adult emergence (%) were determined.

2.3 Determination of thermal constant and development threshold of different *S. litura* stages

Development rate (R) for egg, larvae, puupae and adult stage were calculated as reciprocal of their respective developmental duration (D) such that R = 1/D. Development threshold (T_0) and thermal constant (K) were then determined by regressing development rate on temperature [16], according to rule of the constant sum of effective temperature as under.

Thermal constant = (Temperature - Development threshold) x Development duration

The K was estimated as reciprocal of regression coefficient (b) between development rate and temperature.

K = 1/b

T_0 was determined ratio regression intercept (a) and (b) = T_0 = - a/b

3. Results

3.1 Effect of temperature on developmental time

Significant effect of temperature was recorded on the biological parameters of *S. litura* and which revealed that development duration of life stages *viz.,* egg, larva, pupa, adult and their total life span decreased with increase in temperature from 18±1 to 33±1 ^{0}C (Table 1). Total developmental time was inversely related to temperature and decreased significantly from 64.19 to 27.18 days with temperature from 18±1 to 33±1 ^{0}C. This increase in temperature reduced the incubation period from 9.5 to 3.1 days. Similarly in case of larvae, pupae and adult it varied from 27.45 to 13.50, 15.33 to 6.00, 11.91 to 4.58 days, respectively. Hence, it was observed that *S. litura* could sustain under constant temperature ranging between 18±1 to 33±1 ^{0}C. However, favorable temperature range observed was only between 24 to 27 ^{0}C for *S. litura* egg hatchability, larvae reaching 4th instar, pupae and adult emergence. The lower optimum temperature for the pupal stage compared to eggs and larvae stage suggested a higher sensitivity to temperature because of pupa being in transformational stage in the insect life cycle.

3.2 Effect of temperatures on survivorship

The study demonstrated that the variation in temperature affected the egg hatchability and least of egg hatchability (80.38%) was observed at 33±1 ^{0}C as compared to 97.84% at 27±1 ^{0}C. Number of larvae reaching to 4th instar also decreased from 94.24% at 27±1 ^{0}C to 82.70% at 33±1 ^{0}C (Table 2). With increase in temperature from 18±1 to 33±1 ^{0}C the pupation and adult emergence decreased from 98.71 to 78.48% and 90.05 to 72.30%, respectively. The total survival rate of pupa and adults of *S. litura* at variable temperature recorded least survival of 85.53 and 81.43%, respectively at all temperature regimes as compared to egg hatchability and larvae reaching 4th instar which were 91.07 and 87.91%, respectively. The overall survival of *S. litura* was 74.81, 80.52, 85.84, 88.67, 76.40 and 70.04% at 18±1, 21±1, 24±1, 27±1, 30±1, and 33±1 ^{0}C, respectively. Thus temperature had influenced greatly on survival irrespective of stage of the of *S. litura.*

3.3 Determination of threshold temperature and thermal constant for *S. litura*

Regression method provides thermal constant and development threshold values for different development stages of *S. litura*. Regression equations for threshold temperature and thermal constant were developed for eggs as Y=0.029 X -0.3468 for larva Y= 0.00029 -0.031 for pupa Y= 0.0061-0.0582 and for adults to oviposition as Y= 0.0093 X -0.1022 (Table 3). Development of temperature threshold was observed as 11.93, 10.68, 9.54 and 10.98 for eggs, larvae, pupa and adults respectively with corresponding thermal constant values being 34.48, 344.82, 163.93 and 107.52 degree days (DD).

Table 1: Effect of temperature on development of different stages of *Spodoptera litura* on jute

Temperature (°C)	Developmental time (days)				
	Egg	Larvae	Pupae	Adult	Total life span
18±1	9.5±0.70	27.45±1.50	15.33±1.28	11.91±1.89	64.19±2.86
21±1	7.5±0.60	25.42±1.51	13.11±1.13	10.20±1.75	56.23±2.54
24±1	6.5±0.50	22.16±1.16	10.38±1.54	8.80±0.74	47.84±1.47
27±1	4.5±0.50	18.50±0.95	9.20 ±0.74	6.67±1.02	38.87±1.28
30±1	3.3±0.60	16.00±1.58	7.40 ±0.51	5.67±0.77	32.37±1.09
33±1	3.1±0.00	13.50±1.29	6.00±0.85	4.58±0.49	27.18±1.64

Table 2: Effect of temperature on mean percent survival of *Spodoptera litura* under laboratory conditions

Temperature (°C)	Egg hatchability (%)	Larvae reaching 4th instar (%)	Total pupation (%)	Adult emergence (%)	Overall Survival (%)
18±1	90.35	84.22	81.45	76.20	74.81
21±1	92.80	88.37	87.83	81.45	80.52
24±1	93.61	90.81	90.71	89.13	85.84
27±1	97.84	94.24	93.60	90.05	88.67
30±1	91.52	87.25	81.22	79.83	76.40
33±1	80.38	82.70	78.48	72.30	70.04
Mean	91.07	87.91	85.53	81.43	79.38

Table 3: Determination of threshold temperatures and thermal constant for different developmental stages of *Spodoptera litura*

Developmental stage	Regression equation	Thermal constant (K) (K=1/b)	Temperature threshold (T_0) (T_0= a/b)	R^2
Eggs	Y= 0.029 X -0.3468	34.48	11.93	0.92
Larvae	Y= 0.0029 X -0.031	344.82	10.68	0.89
Pupae	Y=0.0061 X -0.0582	163.93	9.54	0.88
Adults to lay Egg	Y=0.0093 X -0.1022	107.52	10.98	0.84
Egg to egg	-	650.75	-	-

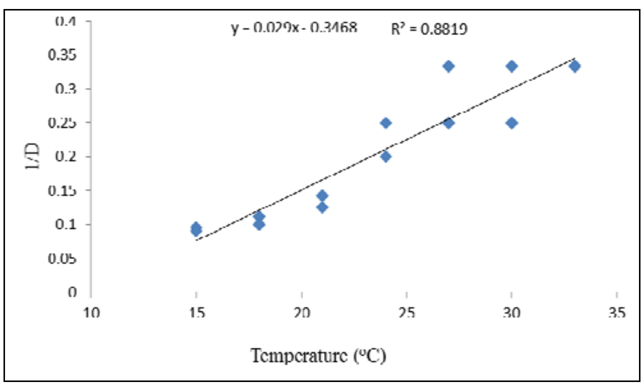

Fig 1: Regression between different temperature and mean duration of incubation period for eggs

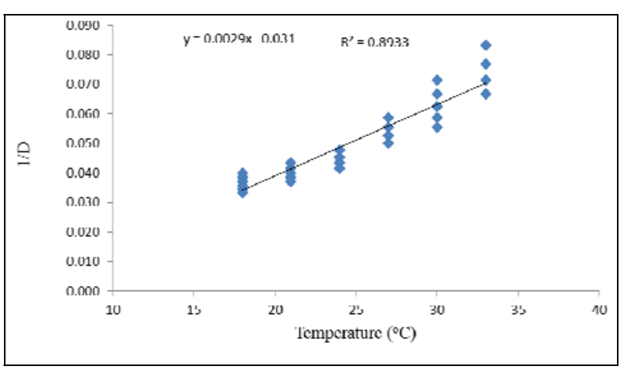

Fig 2: Regression between different temperature and mean duration of incubation period for larvae

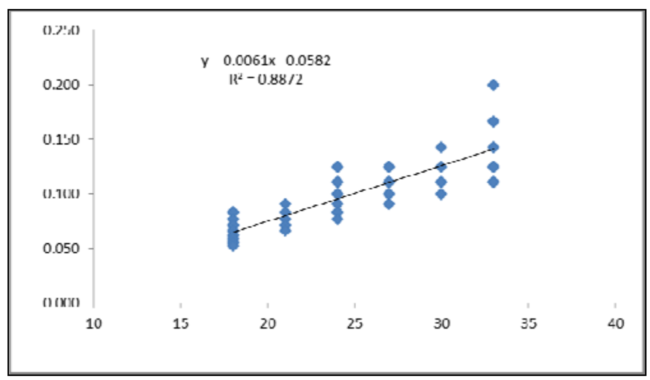

Fig 3: Regression between different temperature and mean duration of incubation period for pupae

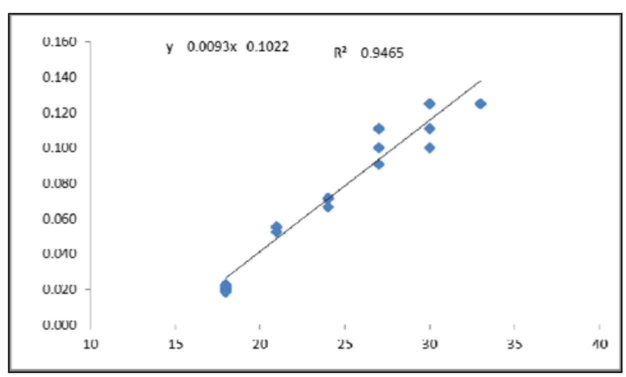

Fig 4: Regression between different temperature and mean duration of incubation period for adults to lay eggs

4. Discussion

Each species has an ecological maxima and minima within which its development rate increases with rise in temperature but decreases beyond it. Generally lower temperatures result in a decrease in the rate of development and an increase in duration of the time of each developmental stage [17]. In the present study, developmental durations of *S. litura* eggs (9.5±0.70 days), larvae (27.45±1.50 days), pupae (15.33±1.28 days) and adult (11.91±.89 days) reared on jute leaves were longest at 18±1 ^{0}C, whereas the durations were shortest at 33±1 ^{0}C (eggs: 3.1±0.00 days, larvae: 13.50±1.29 days, pupae: 6.00±0.85 days and adult: 4.58±0.49 days). The developmental period decreased with increasing temperature, as expected within the range of favorable temperature and duration of all developmental stages. Similar trend of development duration with temperature has also been observed in earlier studies [11, 18, 15]. Developmental period of different stages of *S. litura* was inversely related to temperature and it decreased significantly from 64.19±2.86 to 27.18±1.6 days. Similarly, the average length of time taken to complete life cycle of *S. litura* was found to be 29 and 26 days during the near future of climate change [19].

The survival of *S. litura* under various temperatures revealed that the survival rate of 91.07, 87.91, 85.53 and 81.43% was observed on egg, larva, pupa and adults respectively at different temperature regimes of 18±1 to 33±1 ^{0}C. Pupae and adults were the stages where *S. litura* suffered the highest mortality (81.43-85.53%) irrespective of temperatures. The highest survival (91.07%) was recorded during egg stage. Similarly, the highest survival of eggs (93.0%), larvae (65.0%) and pupae (91.0%) were observed at 20 °C, 30 °C and 25 °C, respectively. Overall survival of *S. litura* stages varied from 70.04% at 18±1 ^{0}C to 88.67% at 33±1 ^{0}C [7] whereas, the temperature greatly affected egg and pupal periods but had little effect on hatching and adult emergence of pink borer, *Sesamia inferens* [20]. The overall survival of *S. inferens* stages varied from 72.5% at 18±1 ^{0}C to 84.5% at 33±1 ^{0}C. Temperature thus influenced incubation period more than it influenced egg hatchability, pupation and adult emergence [15].

The linear regression equations describe the relationship between optimum temperature threshold and development rate for each life stage of *S. litura*. Temperature dependent development threshold depicted the temperature up to 27±1 ^{0}C to be positively correlated with *S. litura*. The development rate as a function of temperature increased linearly for all the immature stages of *S. litura* until approximately 34–36 °C, after which it became non-linear. The extreme temperature of 38 °C was found lethal to larval and pupal stages of *S. litura* wherein no development to the next stage occurred [7]. Similar trend were observed during the present study also. Development of temperature threshold was determined as 11.93, 10.68, 9.54 and 10.98 for egg, larva, pupa and adults with corresponding thermal constant values being 34.48, 344.82, 163.93 and 107.52. These results were slight deviations from earlier studies [21, 12, 22] which might be attributed to differences in rearing conditions and host plant used as larval food. Thus total thermal constant requirement to complete a generation was 650.75 DD whereas, Based on Ikemoto- Takai model and estimated that *S. exigua* required 311.76 DD above a lower threshold temperature of 12.45 for development from egg to adult eclosion [23]. Within favorable temperature range, the development rate of a species increases but it decreases beyond upper temperature threshold. Likewise, fecundity and survival are also affected on either side of favorable temperature range [24]. The linear model was fitted appropriately to the data for the development rate of egg, larva, pupa and adult stages at the temperature ranges of 18 ^{0}C to 33 ^{0}C (Table 3). The linear regression co-efficient values (R^2) for egg, larva, pupa and adults ranged between 0.92 and 0.84 (Fig. 1, 2, 3 & 4). The study is in confirmation that *S. nonagrioides* the non-linear regression coefficient values (R^2) ranged between 0.97 and 0.99 [18]. These thermal information helpful to develop phenology model which can be useful for integrated pest management (IPM) decision making and pest dynamics under changing climatic scenarios and also serve valuable tool in forecasting infestations monitoring, prediction of appearance of insect stages and timing of insecticide application.

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6. References

1. Rahmam S, Khan MR. Pest complex of jute and their management. In: Sustainable pest management (Ed. D. Prasad). Daya Publishing House, New Delhi, 2007, 352-372.
2. IIE. Distribution Maps of Plant Pests, Wallingford (UK): CAB International. 1993, 61.
3. EPPO. PQR database: European and Mediterranean Plant Protection Organization, Paris, France. Available: http://www.eppo.int/DATABASES/pqr/pqr.htm. 2 July, 2016
4. Selvaraj K, Gotyal BS, Gawande SP, Satpathy S, Sarkar SK. Arthropod biodiversity of jute and allied fibre crops. In. Economic and ecological significance of arthropods in diversified ecosystems- Sustaining regulatory mechanisms (Eds. Chakravarthy AK, Sridhara S). Springer publication. ISBN 978-981-10-1524-3. 2016, 195-221.
5. Das LK, Laha SK, Pandit NC. Entomology. In: Fifty Years of Research on Jute and Allied Fibres Agriculture, ICAR-Central Research Institute for Jute and Allied Fibres, Barrackpore. 1999, 142-64.
6. Lange H, Okland B, Krokene P. Thresholds in life cycle of the spruce bark beetle under climate change. International Journal Complex Systematics. 2006; 1648:1-10.
7. Fand BB, Nitin TS, Santanu KB, Minhas PS. Temperature impacts the development and survival of common cutworm (S*podoptera litura*): Simulation and visualization of potential population growth in India under warmer temperatures through life cycle modelling and spatial mapping. PLoS One. 2015; 10(4):e0124682 DOI:10.1371/journal.pone.0124682.
8. Bale J, Masters GJ, Hodkins ID, Awmack C, Bezemer TM, Brown VK. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Global Change Biology. 2012; 12; 8:1-16.
9. Briere JF, Pracros P, Le Roux AY, Pierre JS. A novel rate model of temperature-dependent development for arthropods. Environmental Entomology. 1999; 28:22-29.
10. Gedia MV, Vyas HJ, Acharya MF, Patel PV. Life table, rate of increase and stable age distribution of *Spodoptera litura* (Fabricius) on cotton. Annals of Plant Protection Sciences. 2008; 16:62-65.
11. Rao CVR, Wightman JA, Rao DVR. Threshold

temperatures and thermal requirements for the development of *Spodoptera litura* (Lepidoptera: Noctuidae). Environmental Entomology. 1989; 18:548-551.

12. Prasad JV. Comparative life table studies of *Spodoptera litura* Fabricius and *Spodoptera exigua* on FCV tobacco seedlings under southern light soil conditions. Tobacco Research. 2004; 30:42-47.
13. Bharathi JL, Srieedhar U, Kishore B, Prasad JV, Prasad Rao JAV. Life table studies of *Spodoptera litura* on different types of tobacco. Tobacco Research. 2007; 33:36-42.
14. Patil RA, Mehta DM, Jat BL. Studies on life fecundity tables of *Spodoptera litura* Fabricius on tobacco *Nicotiana tabacum* Linnaeus. Entomology, Ornithology and Herpetology. 2014; 3:1-5.
15. Selvaraj K, Chander S, Prasannakumar NR. Determination of thermal constant and development threshold of Pink stem borer, *Sesamia inferens* Walker. Proceedings of National Academy of Sciences, India Section B Biological Sciences. 2014; DOI 10.1007/s40011-014-0348-1.
16. Kipyatkov VE, Lopatina EB. Intra-specific variation of thermal reaction norms for development in insects: new approaches and prospects. Entomological Reviews. 2010; 90(2):163-184.
17. Manimanjari D, Srinivasa Rao M, Swathi P, Rama Rao CA, Vanaja M, Maheswari M. Temperature- and CO_2-Dependent life table parameters of *Spodoptera litura* (Noctuidae: Lepidoptera) on sunflower and prediction of pest scenarios. Journal of Insect Science. 2014; DOI: http://dx.doi.org/10.1093/jisesa/ieu159 297.
18. Andreadis SS, Kagkelaris NK, Eliopoulos PA. Temperature-dependent development of *Sesamia nonagrioides*. Journal of Pest Science. 2013; 86:409. DOI:10.1007 /s10340-013-0490-1.
19. Srinivas Rao M, Rama Rao CA, Vennila S, Manimanjari D, Maheswari M, Venkateswarlu B. Estimation of number of generation of *Spodoptera litura* on peanut in India during near and distant future climate change scenarios, Science Research Essays. 2014; 9(7):195-203, DOI: 10.5897/ SRE2013.5783.
20. Areekul S, Chamchanya T. Effect of humidity, temperature and light on the growth and development of *Sesamia inferens* Walker. Kasetsart Journal. 1973; 7(2):65-75.
21. Miyashita K. Effects of constant and alternating temperatures on the development of *Spodoptera litura* F. (Lepidoptera: Noctuidae). Applied Entomology and Zoology. 1971; 6:105-111.
22. Zhu S, Lu Z, Chen L, Yu W, Zhang S. Effect of temperature and food on *Spodoptera litura* population, Ying Yong Sheng Tai Xue Bao. 2000; 11(1):111-4.
23. Karimi-Malati A, Fathipour Y, Talebi AA. Development response of *Spodoptera exigua* to eight constant temperatures: Linear and nonlinear modeling, Journal Asia-Pacific Entomology. 2014; 17(3):349-354. DOI: 10.1016/j.aspen.2014.03.002.
24. Sujithra M, Chander S. Simulation of rice brown planthopper, *Nilaparvata lugens* (Stal.) population and crop-pest interactions to assess climate change impact, Climatic change. 2013; 121(2):331-347. DOI: 10.1007/s10584-013-0878-1.