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Temperature dependent phenological synchrony between host-fruit availability and occurrence of Oriental fruit fly, *Bactrocera dorsalis*, a crucial link to study climate change

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Abstract

Importance of using host plant phonological events in conjunction with weather variables to predict pest activity was attempted. Temperature dependent phenological synchrony was observed between host fruit availability and fruit fly trap catch in oriental fruit fly, Bactrocera dorsalis. *Using soft computing tool and traditional linear regression, the fruit fly prediction accuracy could be enhanced upto 92% using host-fruit availability and temperature together. This study clearly showed that both host-fruit availability and fruit fly occurrence exhibited a synchronous response to temperature, one of the important indicators studied to assess the long term impacts of climate change.*

Keywords: Mango fruit fly, *Bactrocera dorsalis*, phenological events, climate variables

Introduction

Insects are poikilothermic, meaning their development depends on the temperature to which they are exposed in the environment, a foundational concept for insect population prediction models (Herms, 2004, Kamala Jayanthi and Verghese, 2011). Thus, insects are very sensitive to changes in temperature, which may affect their activity, development, phenology, and survival directly or indirectly through host-plant phenology shifts or effects of temperature on host chemistry and at the same time, many phytophagous insects are able to quickly adapt to new environments, provided their host plants are present (Karban and Strauss, 2004). Thus, amidst the continuous changing climatic scenarios in both temporal as well as spatial scales, a crucial relationship does exist between the host-plant phenology and occurrence of their herbivores indicating an important co-occurrence or ecological overlap.

Oriental fruit fly, *Bactrocera dorsalis* Hendel (Diptera: Tephritidae), is a highly polyphagous pest of a wide range of tropical and subtropical fruits and particularly in mango, *Mangifera indica* L., it causes enormous losses to farmers (Verghese and Kamala Jayanthi, 2001; Kamala Jayanthi and Verghese, 2011). Mango, inspite of being preferred host-plant, the restrictive fruiting of mango and the high polyghagy of *B. dorsalis* allows this fruit fly to survive on other cultivated as well as wild fruits. Immediately after mango harvest, during off-season, *B. dorsalis* survives mainly on its alternative host-plant, guava (*Psidium guajava* L.) thereby completing several generations within a year (Kamala Jayanthi and Verghese, 2011). Thus, host-fruit availability and abundance of cultivated fruits were recognized as crucial factors for the existence of *B. dorsalis* (Harris *et al.,* 1993; Ye and Liu, 2005a, Kamala Jayanthi and Verghese, 2011). Relationships between fruit availability and *B. dorsalis* members have also been observed in case of West Indian fruit fly, *Anastrepha obliqua* Macquart, Mexican fruit fly, *Anastrepha ludens* (Loew) (Aluja *et al.*, 1996) and *B. dorsalis* (Tan and Serit, 1994) that suggested fruit fly populations were affected directly by host-fruit availability. Apart from the host-fruit availability, among the abiotic variables, monthly average minimal temperatures were found to be an important factor influencing the fruit fly population dynamics (Liu and Ye, 1982; Verghese and Sudha Devi, 1998; Ye and Liu, 2005b; Kamala Jayanthi and Verghese, 2011). The importance of phenological events of host plants for predicting pest activity was studied extensively (Herms, 2004). However, studying the temperature dependent relationship between the host-plant phenology and pest occurrence will definitely help to understand and assess the effect of climate variations on host-plant and pest interactions as well. In the present study, an attempt was made to understand the existence of any synchronous relationship between the host-fruit availability and temperature with reference to *B. dorsalis* trap catch using traditional regression methods as well as soft computing tools *viz.,* artificial neural networks.

Materials and methods

Monitoring of the fruit flies was done on a fortnightly basis (from 1st June, 2000 through 17th June, 2002) using methyl eugenol traps at Indian Institute of Horticultural Research, Bangalore. The flies attracted to each trap were obtained fresh and brought immediately to the laboratory for identification using the characters described by Drew and Hancock (1994). Parallel field observations were recorded on the host-fruit availability of *P. guajava* plants and scored visually on per cent basis (0-100). In addition to fruit fly trap catches and host-fruit availability data, the significant concurrent weather parameters including maximum temperature (°C) and minimum temperature (°C) were collected for every fortnight from the meteorological section of the Institute located in close proximity of the study orchard.

The data were analysed through both linear regression analysis (Little and Hills, 1978) as well as Artificial Neural Networks (ANNs). The application of ANNs is well known for better understanding of the influence of input variables particularly relevant for biological processes that exhibit interdependent functionality based on several variables (Kamala Jayanthi *et al.,* 2011). For ANN, Elman backpropagation network trained with Levenberg-Marquardt algorithm was used for programming in Matlab 7.0. The selected ANN structure was 3-9-6-1 (i.e., 3 input layer nodes-host-fruit availability, min. and max. temperatures; two hidden layers each with 9/6 nodes, respectively; and one output layer node-fruit fly trap catch) where mapping the hidden layers and respective nodes was carried out based on trial and error method, as there is no standard methodology for selecting the same (Abdusselam, 2007). The applied transfer functions are two hyperbolic tangent-sigmoid and one log-sigmoid transfer function. The whole data were divided in to two sets *viz.,* training and validation and was used accordingly for ANN analysis. The accuracy of output was measured using statistical indices *viz.,* root mean square error (RMSE) and regression coefficient (R^2).

Results and discussion

The correlation analysis exhibited a strong significant ($P<0.01$) positive relationship between host-plant phenological trait, fruit availability-minimum temperature (r = 0.68**) (Fig.1) and fruit availability-maximum temperature (r = 0.38**). The variability in the host-plant fruiting (y) was explained to the tune of 45% by abiotic variables, minimum and maximum temperature ($y = 2.87_{min.Temp.} + 0.967_{max.Temp.} - 60.6527$, $R^2 = 0.45$; $F = 20.21$, $P<0.001$) alone through multiple regression. However, among these, the minimum temperature alone could explain the variability in the host-fruit availability to the tune of 42% ($y = 3.1083_{min.Temp} - 36.253$; $R^2 = 0.4228$; $F = 57.03$, $P<0.001$) through linear regression. The polynomial order (2) could enhance the R^2 up to 48% ($y = 0.4334x2 - 11.432x + 82.126$; $R^2 = 0.4754$) (Fig. 2). Further, both these variables exhibited strong significant positive correlation with fruit fly, *B.*

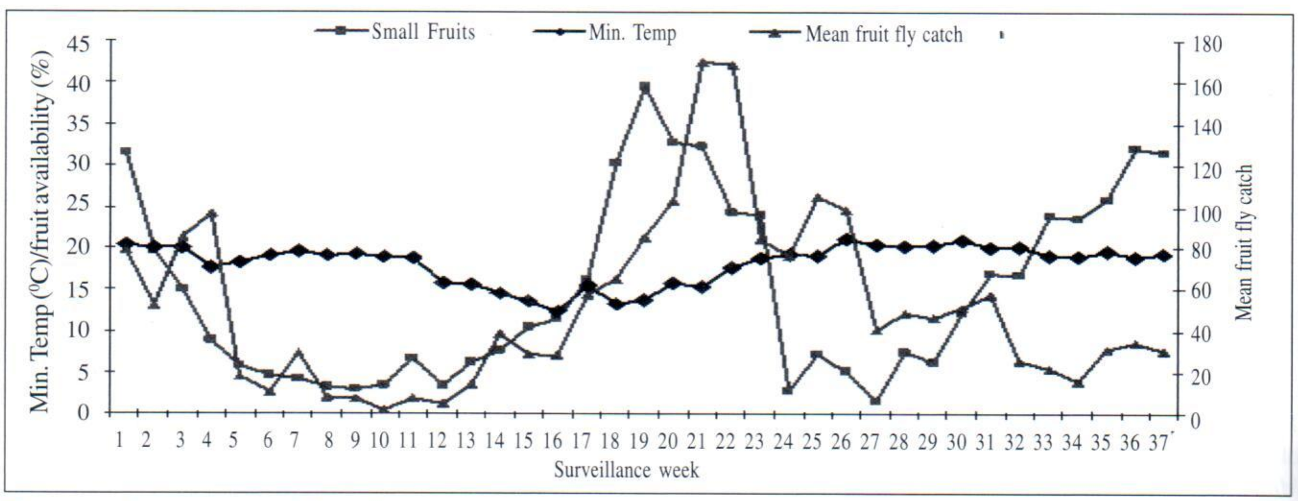

Figure 1. Occurrence of fruit fly, *B. dorsalis* in relation to host-fruit availability and minimum temperature r = 0.68**

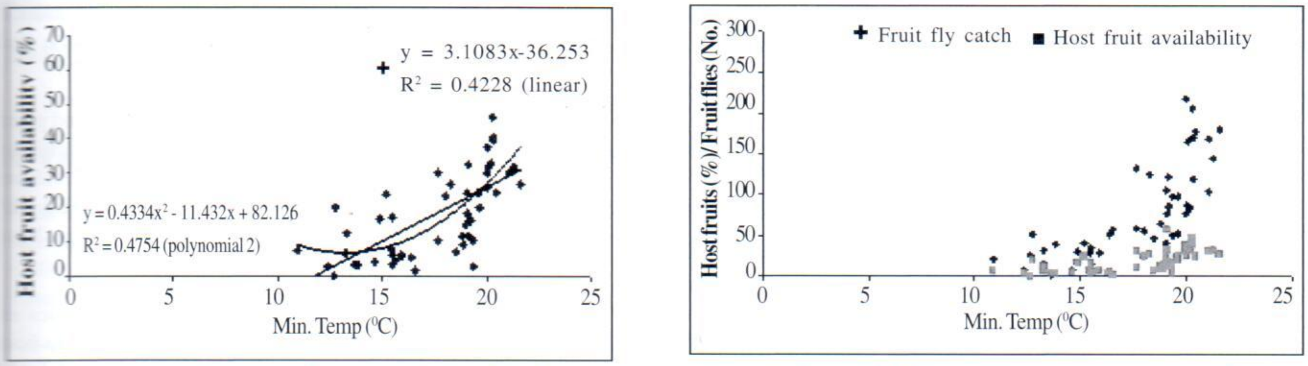

Figure 2. Scatter diagram showing relationship between the a. host-fruit availability-minimum temperature b. host-fruit availability-fruit fly, *B. dorsalis* trap catch (†Kamala Jayanthi and Verghese, 2011)

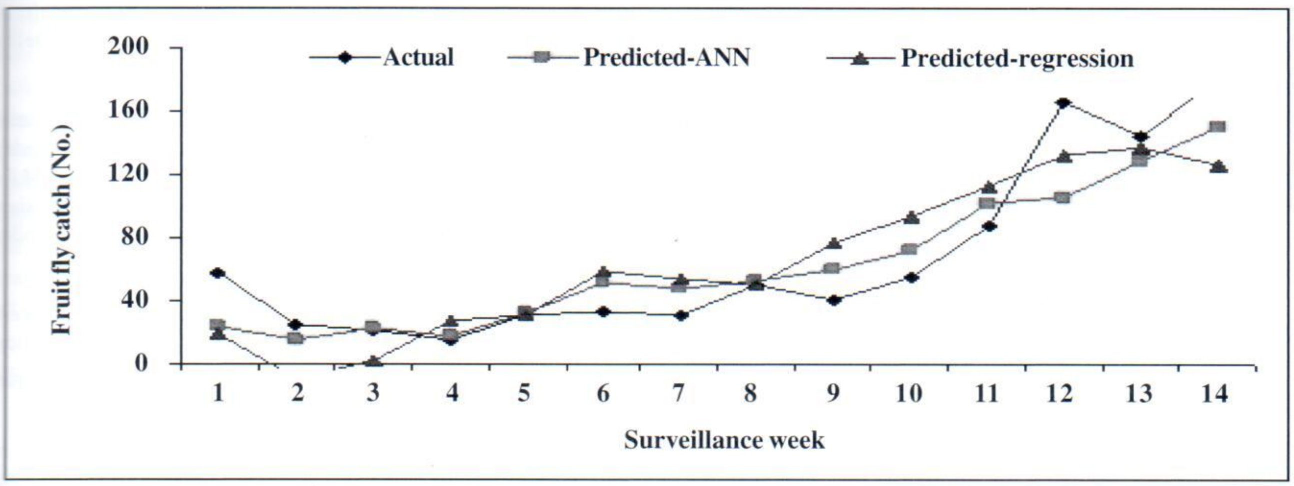

Figure 3. Trend of actual and predicted fruit fly trap catch using ANN and linear regression

dorsalis trap catch (0.68**- min. temperature and 0.81** - small fruits, and could predict the fruit fly trap catch to the tune of 70% together (Kamala Jayanthi and Verghese, 2011).

In the present study also, the abiotic variable, temperature along with host fruit availability could explain the variability in the fruit fly trap catch to the tune of 69% ($y = 6.12_{min. Temp.} + 0.35_{max. Temp}. + 2.94 - 95.85$, $R^2 = 0.69$; $F = 37.29$, $P<0.001$) through multiple regression and to the extent of 92% ($R^2=0.92$) with RMSE of 23.07 using artificial neural networks. Further, validation of optimized model (the observed fruit fly catch values were compared to predicted values) through regression as well as ANN methodologies clearly indicated that the models could predict the trap catch efficiently (Fig.3). Using soft computing tools *viz.*, quasi-newton artificial neural networks, QN-ANN further enhanced the fruit fly prediction accuracy upto 92% using host-plant phenology and weather variables (Kamala Jayanthi *et al.*, 2011). This study clearly showed that both host-fruit availability and fruit fly occurrence exhibited a synchronous response to temperature, one of the important indicators studied to assess the long term impacts of climate change. Earlier studies emphasized the importance of biological calendars consisting of host plant phonological sequences *viz.*, flowering, fruiting for use in predicting the insect activity accurately (Sridhar and Reddy, 2013). Similarly, the present study established that vulnerable host plant phenological events (eg. Host fruit availability for fruit fly, *B. dorsalis*) can serve as important clues to predict the insect activity, particularly; in case of perennial horticultural crops like fruits these phenological stages in conjunction with weather improve the efficacy of insect prediction.

Thus, studying the host-plant phenological events as indicators for fruit fly activity in relation to temperature, will help not only to have better understanding of impact of climate change on fruit fly incidence but also to quantify its future impacts.

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