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Prediction of mango hopper, *Idioscopus nitidulus* (Walker) based on diurnal variations under south Gujarat climatic conditions

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Abstract
An experiment was carried out five consecutive years (2012-16) on mango to study the role of weather parameters on population dynamics of mango hopper, *Idioscopus nitidulus* (Walker) under south Gujarat climatic conditions. The results revealed two population peaks of hopper during the study period starting with new flush stage followed by another peak during flowering cum fruit set stage of the crop. The correlation of hopper population with diurnal variation ($P<0.01$) was positively significant while strong significant negative correlation with temperature (minimum, day and night), relative humidity (morning and evening), rainfall and heat sum ($P<0.01$) was also established. Further, optimized model was developed using diurnal variation which predicted hopper population based on high R value (77%). This forewarning model can be used for decision making in Integrated Pest Management programme, but future validation is needed to improve its predictive efficacy.

Keywords: Climate, correlation, diurnal variation, hopper, mango, regression, population dynamics, weather parameters

Introduction
Mango (*Mangifera indica* L.) is an important fruit crop in tropical and sub-tropical regions of India being cultivated over an area of 2.20 million hectares with total production of 18.64 million MT contributing 40 per cent of the total world production. Among Indian states, Gujarat contributes 1.24 million MT production [1]. Mango hoppers are major and wide-spread monophagous pest that damages each crop stage from emergence of new flush to fruiting stages [2-4]. Both nymphs and adult hoppers suck cell sap from young leaves, tender shoots, inflorescences or panicles and rachis of the young fruits which cause non-setting of flowers and dropping of the immature fruits. Hoppers also excrete huge quantities of honey dew resulting in sooty mould formation, thus affecting the photosynthesis of the plant [2, 11].
The aim of the present study was to study the population of mango hopper as influenced by the weather parameters under south Gujarat agro-climatic conditions. Several worker have studied the population dynamics of mango hopper in relation to weather parameters in different parts of India in different climatic conditions [3, 7, 5, 12] but, it is lacking in South Gujarat, a major mango production hub in Western part of this scountry. Analysis of this relationship within South Gujarat will provide essential information for understanding the population dynamics of mango hopper in the region and also for generating scientific data for formulating area specific Integrated Pest Management (IPM) strategies.

Materials and Methods
The experiment study was conducted during five consecutive mango seasons (2012-16) in Valsad district of south Gujarat, India at 26 locations. Hopper population was recorded at standard meteorological week wise interval on five randomly selected trees and expressed as number of hoppers per panicle or twig or sweep at 2-3 meter height by visual count method without disturbing the relevant plant part [10]. Standard week wise weather data *viz.*, temperature (maximum and minimum), relative humidity (morning and evening), rainfall, wind speed, and evaporation rates were recorded from meteorological observatory located within the experimental site. Using weather data, indices like day temperature (DT), night temperature (NT), diurnal variation (DV) and heat sum (HS) were calculated following [13] as given below:

$DT = T_{max} - 0.4 (T_{max} - T_{min})$
$NT = T_{min} + 0.4 (T_{max} - T_{min})$
$DV = DT - NT$
$HS = \sum (T_{max} + T_{min})/2\text{-}T_{\text{Base temperature}}$
Where, T_{Base} is base temperature which was taken as 17.9 °C for mango [6].

Correlation and regression analysis were wotked out to find the association between weather parameters and population of mango hopper. A scattered diagrams as well as trend line were also drawn to study the degree of relationship between hopper and most significant weather parameter. The model performance measures such as root mean squared error (RMSE), mean squared error (MSE) were also computed.

Results and Discussion

Weather conditions during the study periods

The climatic conditions of south Gujarat played an important role in dynamics of mango hopper. Maximum and minimum temperature varied from 29.25 to 37.02 °C and 9.17 to 26.05 °C, respectively. An average temperature ranged 18.84 to 33.20 °C throughout the year. While, minimum and maximum relative humidity was observed 35.01 to 95.56%, with an average value 55.18 to 84.03%. Lowest and highest wind speed (1.18 to 7.95 km/hr) was observed in south Gujarat agroclimatic conditions. Average rainfall (2168.56 mm) was recorded during study periods.

Population dynamics of mango hoppers

The results pertaining to the studies based on population dynamics of mango hopper (Fig.1) revealed that hoppers attacked at vegetative as well as reproductive stages of the plant. The maximum population was noticed during new flush and flowering stages of the plant. While, hoppers were recorded more or less throughout the year except during rainy months wherein population on twig or trunk was very low or nil (Fig.1). On the basis of pooled results, maximum hopper (2.04/panicle) were recorded during 11th standard meteorological week (SMW) when the prevailing maximum (35.27ºC) and minimum temperature (14.78 ºC), relative humidity morning and evening (41 to 76%) and wind velocity (2.76 km/hrs) provided congenial conditions for multiplication of the hopper (Fig. 1). Kumar *et al.,* (2014) [7] reported maximum hopper population during 8th and 9th SMW in full bloom stage of the crop in south Gujarat mango ecosystem. Bana *et al.,* (2018) [2] reported peak occurrence of mango hopper between second week of March to the last week of May. This could be due to formation of inflorescence and fruiting stages of the mango crop being most preferred by the hoppers.

Relationship between hopper and weather parameters

The correlation coefficiants (Table 1) between hopper population and weather parameters was significantly positive with maximum temperature and diurnal variation ('r' = 0.323, $P<0.05$) and ('r' = 0.875, $P<0.01$). While, other weather parameters *viz*., temperature (minimum, day, night and heat sum), relative humidity (morning and evening), rainfall and wind velocity indicated significant negative correlation with hoppers population ($P<0.01$). The present findings conform to the earlier studies by Kumar *et al.,* (2012) [7] reported significant negative correlation of hopper population with temperature (minimum & average), RH (evening & average), rainfall and wind velocity during 1997-2007 in south Gujarat mango ecosystem. Zagade *et al.,* (2010) [14] reported that hopper population had significant negative correlation with relative humidity. Kumari *et al.,* (2008) [8] noticed that hopper population had significant negative correlation with evening RH ('r'=-0.66 and -0.69, $P<.0.01$) in Baneshan and Dashehari cultivars of mango, respectively. Varshneya *et al.,* (2008) [12], Joshi and Kumar (2012) [5] support the present findings and reported that hopper population increased when temperature raised and relative humidity decreased under agro-climatic conditions of Haridwar.

Among the different weather parameters and indices, the highest correlation (0.875**) were obtained with diurnal variation of temperature. Thus, this was used to develop regression equation (Y=-0.51 + 0.40DV; R^2=0.77**) which coud explain 77 percent variatations in hopper population (F=163.80; $P<0.01$). The root mean squared erreor (RMSE) and mean absolute error (MAE) of this model are 0.273 and 0.207, respectively (Table 2). A scatter diagram showing relationship between population of hopper and diurnal varitation is depicted in Fig. 2. It indicated that more than 4ºC difference in temperatures (DV) that increased hopper population during vegetative and flowering cum fruit setting stages of the plant. Kumar *et al.,* (2009) [8], Kumar *et al.,* (2012) [7] reported that abiotic factor contributed to 47.4 and 11.2% variation with hopper population in Dashehari and Alphonso varieties. Lakshmi *et al.,* (2010) [9] observed 25 to 49 per cent variation in hopper incidence in different mango varieties due to abiotic factors prevailed in Andhra Pradesh. Gundappa *et al.,* (2018) [3] develop equation using growing degree days (GDD) that explained 66 per cent variation of hopper population under Lucknow conditions.

Table 1: Correlation coefficient between mango hopper and weather parameters during 2012-2016

Weather parameters	Correlation coefficient (r)
Max. temp.	0.323*
Min. temp.	-0.816**
Morning RH	-0.496**
Evening RH	-0.824**
Rainfall	-0.566**
Wind speed	-0.688**
Evaporation	0.042^{NS}
Day temp.	-0.537**
Night temp.	-0.707**
Diurnal variation	0.875**
Heat sum	-0.640**

* Significant at 0.05 level, ** Significant at 0.01 level, respectively
N=52

Table 2: Step wise liner regression analysis for hopper population with weather parameters

Linear Regression equation	R^2	RMSE	MAE	F_{value}
$Y=-0.51^a + 0.40$ DV	0.77	0.273	0.207	163.80**

[a] =Constant
DV =Diurnal Variation

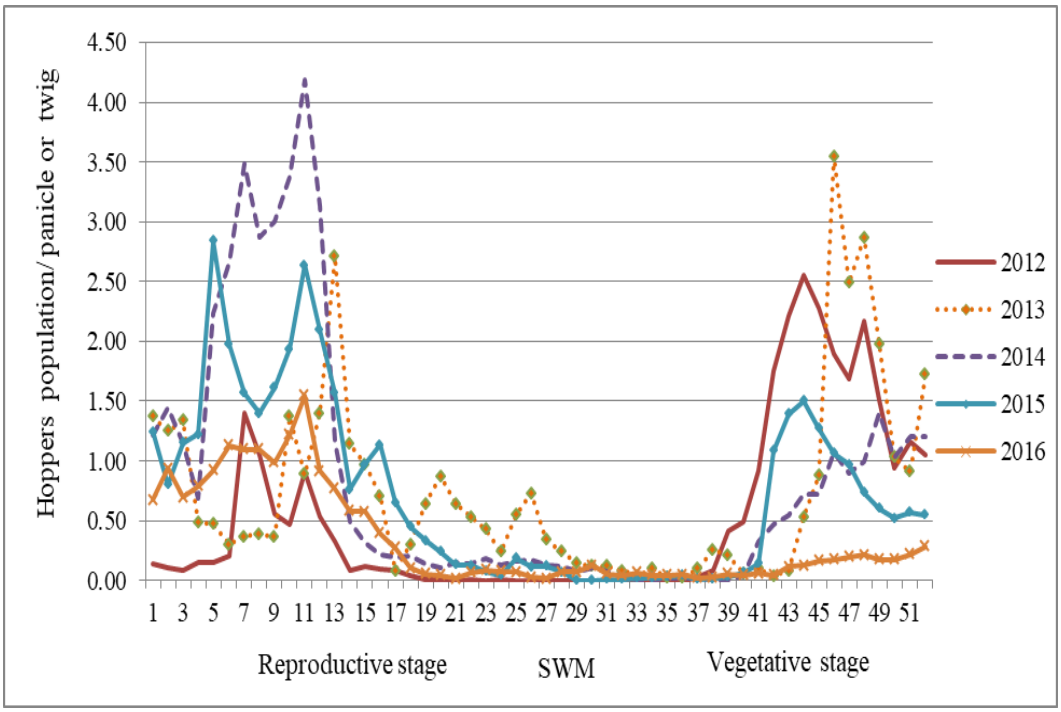

Fig 1: Hopper population trend in last five years (2012-16)

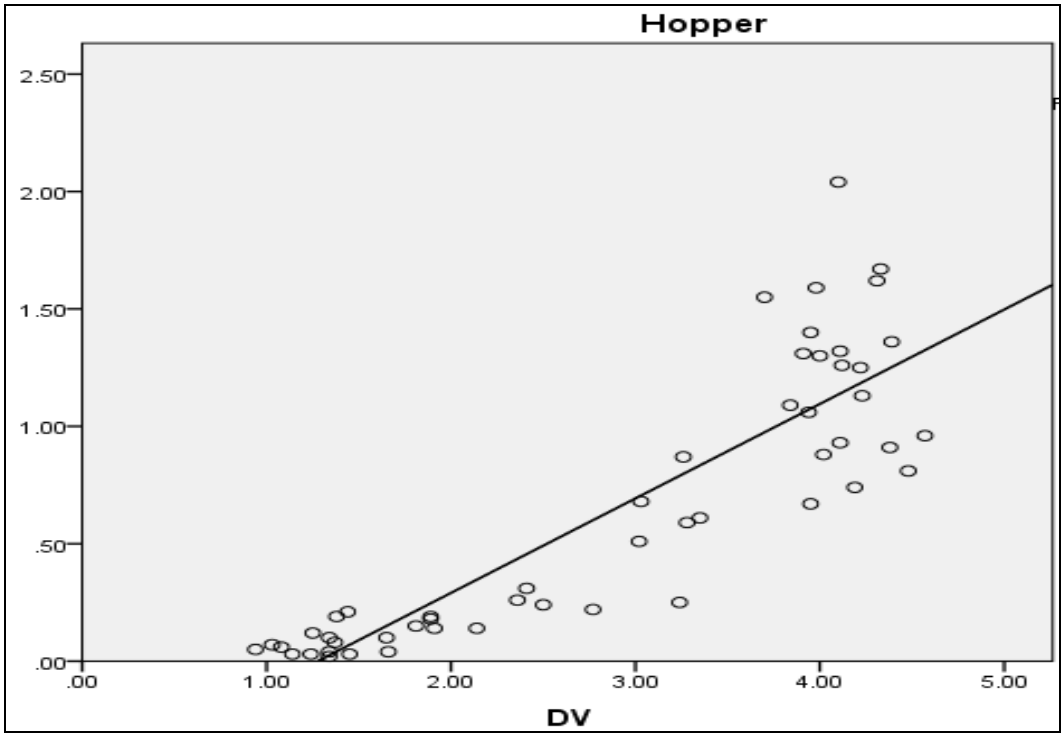

Fig 2: Scatter plot showing the relation between population of hopper and diurnal varitation

Conclusions

The present study clearly indicated that diurnal variation play a strong role for predicting mango hopper population. Diurnal variation of more than 4ºC during vegetative (new flush) and reproductive stages of mango increased hopper population under south Gujarat climatic conditions.

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