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Short Communication

Forecasting of insect pest population in brinjal crop based on Markov chain model

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Brinjal (*Solanum melongena* L.) is one of the most economically important horticultural crop grown in many geographical parts of India. Various pests which attack brinjal crop are brinjal shoot and fruit borer (BSFB), stem borer, whitefly, leafhopper, aphid, epilachna beetle, lacewing bug and red spider mite (Borkakati *et al*., 2019). Among these, BSFB (*Leucinodes orbonalis*) is one of the most destructive pest and is of prime importance. The yield reduction due to its attack could be as high as 70 per cent (Dhandapani *et al*., 2003). Climate change is the long-term changes in the weather patterns in a region. Apart from having direct effects on plant productivity, it can also influence productivity through indirect effects mediated by changes in pests and diseases (Thomson *et al.,* 2010). Climate can act directly on an insect either as a mortality factor or by determining insect growth rate and/or development (Bale *et al.,* 2002). Climate affects the abundance and distribution of any species affecting the insect migration and outbreaks (Parmesan, 2007; Speight *et al.,* 2008). During the past 100 years the global average earth surface temperatures have increased by 0.6°C with 1990's being the warmest decade and 1998 the warmest year (Houghton *et al.,* 2001). In Punjab, a rise in minimum temperature by 0.06°C per year over the past four decades has been reported by Kaur *et al.* (2012). Various weather factors play a key role for the incidence and development of insect pests and understanding of these factors is vital to the study of population dynamics, predicting pest outbreaks and in the development of management strategies.

The knowledge of historical weather data can help farmers for adopting management practices to prevent or reduce the effect of infestation of insects on their crop. The climatic condition of north western plains of India can be classified as subtropical to semi-arid. Temperature during winter season ranges from 2 to 47°C in summer and rainfall ranges from 58 to 96 cm; both extreme exist i.e. chilling condition in winters and very hot during summers (Biwalkar, 2019). For determining dry and wet spell from long term rainfall data, Markov chain model has been used by several researchers (Senthilvelan *et al*., 2012). Robertson *et al.* (2004) reported many possibilities for using the theory of Markov chain in agriculture sector. Keeping in view the utility of Markov chain model for the management of insect pests in vegetable crops, present study was carried out on brinjal crop in Ludhiana region to sort out the exact nature/ degree of relationship, which exists between insect pests and weather factors, with ultimate aim to help the entomologists to develop the best integrated pest management strategies in brinjal.

Dry and wet spell along with initial and conditional probabilities was calculated using Markov chain model. The rainfall data for last 30 years (1986 to 2016) was collected from the Observatory, School of Climate and Agricultural Meteorology, Punjab Agricultural University, Ludhiana. On the basis of standard meteorological week (SMW) initial and conditional probabilities were calculated. Investigations on population dynamics of insect pests in brinjal crop were carried out in Ludhiana for four years from 2016-2019. Ludhiana is located at 30.9°N 75.85°E and has an average elevation of 244 metres from mean sea level. The observations on borer infestation were recorded from 40 randomly selected plants per field and percent fruit infestation was calculated. Temperature, relative humidity (RH) and rainfall data was subjected to correlation with the population fluctuation of BSFB. Regression model was also formulated for estimation of pest population through multiple regression equations using Statistical Analysis System (SAS) software.

Population dynamics of BSFB

Among various insect pests, BSFB was the key pest observed during on brinjal crop during 2016-19. The mean per cent fruit infestation decreased from 28.5 (36th SMW) to 1.1 (48th SMW) as the decrease in temperature was observed during 2016. Similar trend was observed in next two successive years. During 2017 and 2018, the per cent fruit infestation remained high during August month (37^{h} to 43rd

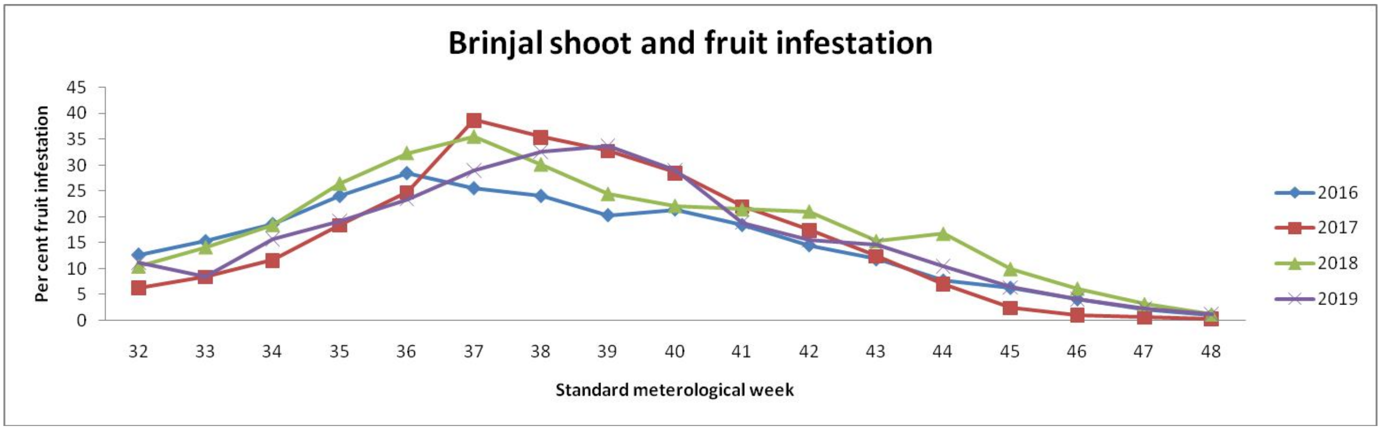

Fig. 1: Incidence of insect pests of brinjal over consecutive four years (2016-19)

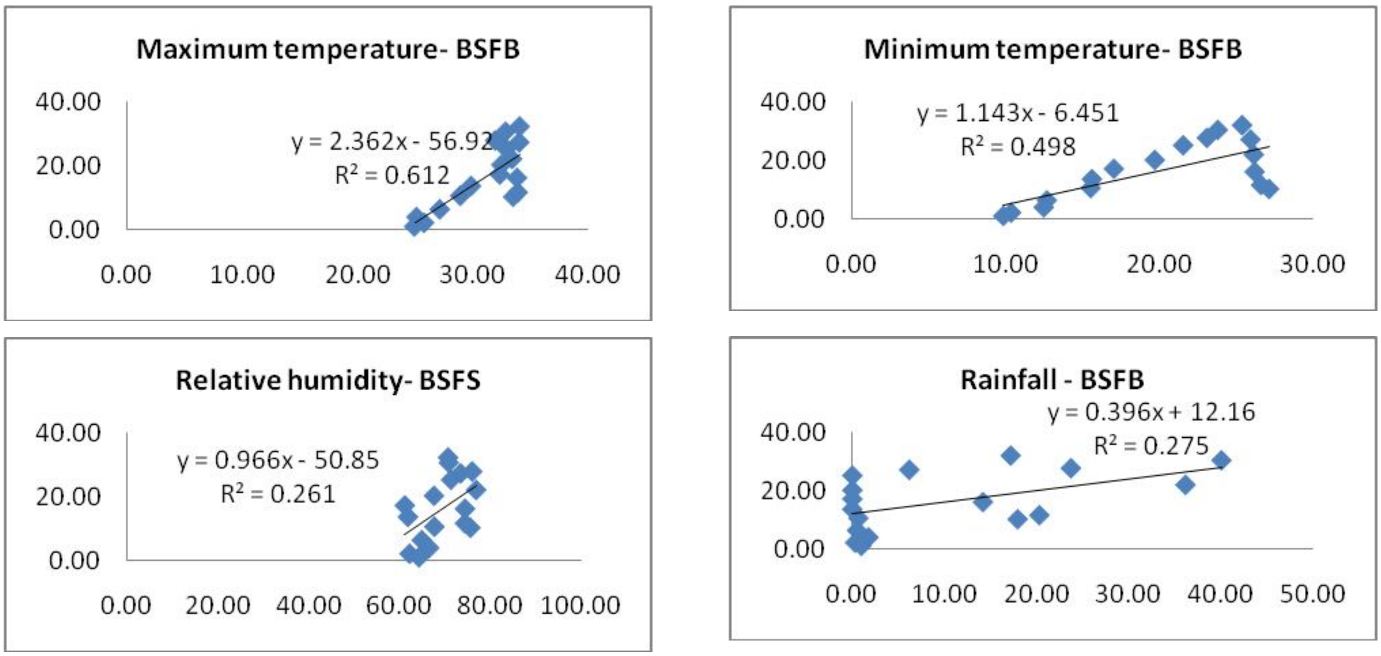

Fig. 2: Scatter plot and regression equation of insect population on brinjal and weather parameters

SMW) but decreased to negligible levels from November onwards with the decrease in temperature. The per cent fruit infestation during 2019 was highest in 39th SMW with range of 33.7 (39th SMW) to 1.2 (48th SMW) per cent fruit infestation (Fig. 1). Four years studies for the seasonal dynamic of BSFB revealed that this pest in fully active from 36-41st SMW with high infestation. In 2017, highest per cent fruit damage as compared to other years was recorded (Fig. 1). It was observed that over four consecutive years, the population of these insect pests on brinjal was affected by temperature, RH and rainfall conditions as indicated in the fluctuations over standard meteorological weeks. Per cent shoot and fruit borer infestation reached its peak in 37th SMW (32.20) with lowest during November in 48th SMW (0.98) (Table 1). From Table 2, we can conclude that higher BSFB infestation was recorded when the maximum temperature ranged between 30.0-34.3^{0}C, minimum temperature 23.1-26.1^{0}C and RH 68.5-79.0%.

Correlation and regression analysis

The relation between insect pests and meteorological parameters over four years revealed that BSFB population showed positive correlation with all the weather parameters i.e. maximum and minimum temperature, RH and rainfall (Table 2). Highly significant positive correlation of BSFB with maximum temperature was recorded (r=0.742). Its incidence was significantly affected by RH and rainfall, with value of correlation coefficient being 0.524 and 0.531, respectively, whereas minimum temperature had non-significant effect with correlation value of 0.342. The value

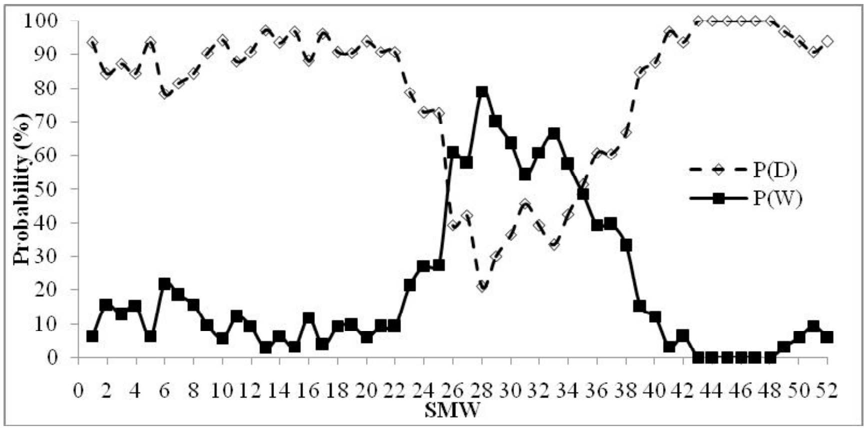

Fig. 3: Initial probability of dry spell and wet spell

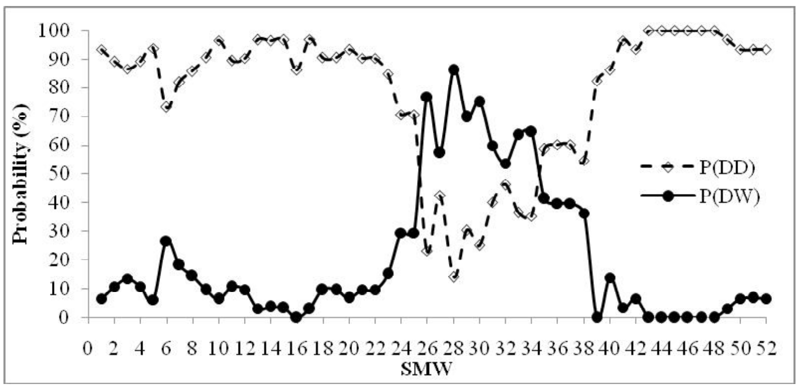

Fig. 4: Conditional probability of dry/dry and dry/wet spell

Table 1: Peak abundance of insect pests on brinjal in four consecutive years with corresponding meteorological parameters

Parameters	Per cent fruit infestation by BSFB			
	2016	2017	2018	2019
Peak	28.5	38.7	35.6	33.7
SMW	36	37	37	39
Max temp (^{0}C)	34.3	33.9	33.4	30.0
Min temp (^{0}C)	26.1	24.5	25.2	23.1
RH (%)	76.1	68.5	69.1	79.0
Rainfall (mm)	4.34	0.0	68.0	0.0

of regression coefficient (R^2) of BSFB incidence was 0.612, 0.498, 0.261 and 0.275 with maximum, minimum temperature, RH and rainfall (Fig. 2). Hence, it was observed that maximum temperature and minimum temperature greatly influenced the BSFB per cent incidence.

Probabilities of occurrence of dry wet spells through Markov chain model

In central part of Punjab (Ludhiana) the initial probability of dry spell starts from the first SMW that continuous for upto 22 SMW with average probability of about 90 per cent. The initial probability of dry spell start decreasing from the 23 SMW onward as the probability of wet spell starts increasing (Fig. 3). During rainy season starting from 25 SMW upto 28 SMW wet period increases till its peak and then recedes upto 48 SMW. As per the Markov chain analysis for the same period reveals that, the conditional probability of dry spell followed by dry spell or a dry spell followed by a wet spell followed the same trend (Fig. 4). Even analysis of the conditional probability of having a wet week followed by a wet week or a wet week followed by the dry week supports the same fact (Fig. 5). The Markov chain model depends on the precedence, therefore to predict next week data, Markov chain model depends on present week data and it was found true for the present study. Insect population pattern followed the climatic condition and as the humidity reduced with temperature, population of BSFB reduced. From 38 SMW onwards when rainfall with temperature and humidity reduced gradually, incidence of BSFB also reduced accordingly up to 42 SMW and when the rain was less with low temperature and humidity from 42 SMW to 48 SMW, the incidence decreased drastically for all recorded seasons (2016 to 2019). Prediction of

Table 2: Correlation coefficient of insect pests of brinjal with weather parameters (pooled 2016-2019)

Correlation coefficient (r)	Max temp (°C)	Min temp (°C)	RH (%)	Rainfall (mm)
Max temp (°C)	1			
Min temp (°C)	0.608	1		
RH (%)	0.757	0.296	1	
Rainfall (mm)	0.849	0.634	0.782	1
BSFB	0.742**	0.342	0.524*	0.531*

* Significant at p= 0.05 level

** Significant at p = 0.01 level

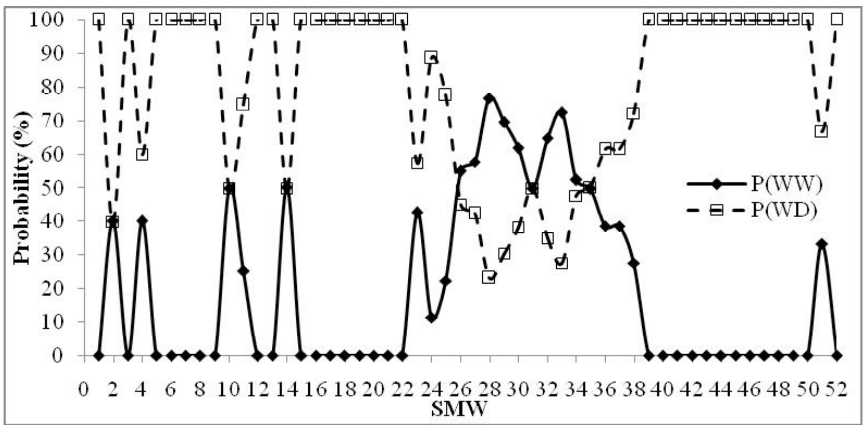

Fig. 5: Conditional probability of wet/dry and wet/wet spell

insects' population through Markov chain method has been well defined throughout growing seasons, as the rainfall pattern decreases the population of insects also decreased accordingly. At the starting of the crop growing season, although the rainfall and relative humidity decreased significantly from 32 SMW to 38 SMW but the population increased due to vegetative growth was prominent during this period and ground cover by crop increased from 20 per cent to 90 per cent, which was helpful for increasing insects' population. As per the Markov chain model predictions, it can be concluded that in Punjab's climatic condition, if the brinjal transplantation is done after 36 SMW the insect population can be managed with less management practices without much affecting the total yield.

Present findings are in corroboration with finding of Patel *et al.* (2015) in which incidence of BSFB was directly influenced by maximum, minimum temperature and RH. Saran *et al.* (2018) also reported that maximum temperature and morning RH showed positive correlation but minimum temperature, evening RH and rainfall showed negative correlation on the incidence of both shoot and fruit infestation by the pest. Anwar *et al.*, (2017) also showed that mean maximum temperature had a significant positive correlation with population of BSFB but non-significant positive correlation with mean minimum temperature and maximum RH.

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