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DISTRIBUTION OF *SPODOPTERA LITURA* (F) IN UTTARAKHAND

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ABSTRACT

***Spodoptera litura* (F.) is one of most important defoliators occurring in Uttarakhand causing significant losses to crops. Its occurrence in the different regions of Uttarakhand was explored through survey conducted from 2018-2020. Environmental variables for current and future climatic scenario were used in Maxent software for Species Distribution Modelling, and QGIS 3.22 software was used for map processing. These analyses and results revealed that highly suitable area for occurrence of *S. litura* increased with change in climatic variables.**

Key words: *S. litura*, Maxent, Species distribution modelling, AUC, ROC, Uttarakhand, QGIS, Climate scenario, CCAFS, North-Western Himalaya

India holds one of the richest biodiversity in world (Ghosh,1996) containing four out of the 34 identified biodiversity hotspots viz., the Himalaya, the Western Ghats, the Indo-Burma region and Sundaland (IUCN, 2019). A number of insect-pests are found in different regions of Uttarakhand which is situated in NW Himalaya of India, since a range of climatic conditions prevail in the region viz., tropical, subtropical, temperate, cold and frigid cold at elevations ranging from below 300 m to above 3400 m.The five physiographic division in which Uttarakhand is divided are: i) Tarai, Bhabhar and Doon Valley; ii) Shivalik ranges and river valley region; iii) Middle/ Lesser Himalaya; iv) Great Himalaya and v) Trans- Himalaya **(**Sati, 2020**)**. Major insect pests groups present in the region include defoliators, sucking pests, borers etc. About 887 species of moths were recorded from only Kumaun region (Smetacek, 2008). *Spodoptera litura* is one such defoliator prevalent in different regions of Uttarakhand causing significant losses to crops. Singh and Sachan (1992) reported that defoliators are plenty at podding and later stages of crop. Climate change in last few decades has influenced distribution of many species (Bale et al., 2002) and hence the prediction of potential distribution of species by use of species distribution model (SDM) has become an important tool for risk assessment and early monitoring of pests (Li and Qin, 2018). Maxent is one of such popular open access software which helps in studying SDM by predicting potential occurrence using simple machine algorithms (Phillips et al., 2006). The present study was conducted with objective of risk analysis and effective management practices by studying the potential quantitative risk of invasion of *S. litura* in North-Western Himalaya of Uttarakhand, identification of climatic factors responsible for potential distribution and correlation of *S. litura* infestation in relation to climate.

MATERIALS AND METHODS

The occurrence data of *S. litura* from different regions of Uttarakhand was collected in a survey conducted from 2018-2020. In total 9 districts viz. Nainital, Almora, Pithoragarh, Bageshwar, Champawat, Udham Singh Nagar, Chamoli, Dehradun and Haridwar were covered and 29 places of these districts were studied during survey. Sampling was done by hand-picking. The geographical coordinates of places were collected from https://power.larc.nasa.gov/data-access-viewer/ and was proofread from Google Earth (Wang et al., 2020). The variables for current climatic scenario were downloaded from Worldclim (https://www.worldclim.org/) at ~30s spatial resolution which represented average for the year 1979-2000. Representative Concentration Pathways, RCP2.6 (minimum greenhouse gas emission scenario), RCP4.5 (medium greenhouse gas emission scenario) and RCP8.5 (maximum greenhouse gas emission scenario) were chosen for future species distribution of *S. litura* (Wang et al, 2018; IPCC, 2014). Climate variables for the future scenario of 2030s (2021-2040) were downloaded from Climate Change, Agriculture and Food Security (CCAFS) website (http://www.ccafs-climate.org/) at ~30s spatial resolution.

Maxent software was used to analyse the potential distribution of *S. litura* in present study (Phillips et al., 2006). Before starting species distribution modelling, all the bioclimatic variables were filtered on the basis of correlation and permutation importance. Highly correlated variables with Pearson's correlation coefficient |r|> 0.8 were eliminated. A total of eight variables i.e. Bio2 (Mean Diurnal Range Temperature), Bio3 (Isothermality), Bio4 (Temperature Seasonality), Bio6 (Min Temperature of Coldest Month), Bio7 (Temperature Annual Range), Bio12 (Annual Precipitation), Bio14 (Precipitation of Driest Month) and Bio15 (Precipitation Seasonality) were reserved for modelling to study current and future distributions. Linear and quadratic features were used in Maxent software because of the small sample size (Kumar et al., 2014) and the filtered reserved environmental layers were imported. In settings of Maxent software "Random seed" was selected and 10 replicate models were run (Wang et al., 2020). In this study the ROC (Receiver Operating Characteristics) curve or AUC (Area Under ROC Curve) was used evaluate model's performance (Cokola et al., 2020). The theoretical values of AUC ranges from 0.5-1 and is an effective threshold-independent measure of model's ability to predict habitat suitability (Wang et al., 2018). The closer the value of AUC is to 1 the better is the performance of model with AUC values 0.5-0.7 as low accuracy, 0.7-0.9 as good accuracy and >0.9 as high accuracy models (Manel et al., 2002). QGIS 3.22 (https://qgis.org/en/site/index.html#) software was used for map processing.

RESULTS AND DISCUSSION

In this study 29 places were surveyed from both hills and plains of Uttarakhand. The weather data and scale of infestation (Vennila et al., 2010) for *S. litura* was observed for different districts and the AUC values from ROC curve were used to evaluate performance of maxent model. Under climate scenario AUC values were 0.999 and 0.853 for the test data and training data, respectively. It was observed in the model that highest percentage contribution was made by Bio6 (i.e. 42.3%) followed by Bio14 (33.9%), Bio12 (18.1%) and Bio3 (5.7%). The potentially suitable area under *S. litura* infestation was found to be 18.4 %. Under three future scenarios of climate change, the suitable area for *S. litura* increased gradually. The test data AUC were 0.987, 0.982 and 0.970 for RCP2.6, RC4.5, RCP 8.5 respectively. In all the three scenarios the highest percent contribution was made by Bio6 i.e. 55.7% in RCP2.6, 66.6% in RCP4.5 and 59.7% in RCP8.5 climate change scenario. The potential area under distribution was found to be 48.27%, 49.72% and 52.53% under RCP2.6, RCP4.5 and RCP8.5 climate change scenario, respectively. *S. litura* is an important economic polyphagous lepidopterous pest belonging to the family Noctuidae (CABI Datasheet, 2018). Life cycle of *S. litura* is about five weeks (EPPO, 2015), the eggs are generally laid in batches of 200-300 on underside of host leaves and the incubation period is about two days at 35°C and 14 days at 15°C (Hill, 1983 and Fand et al., 2015). Temperature is one of the key factors in growth and development of *S. litura* and both the higher as well as lower temperature influence the survival and development of this insect (Prasad et al, 2021; Srinivasrao and Prasad, 2020; Rao et al., 2014). Climate change over the last three decades has influenced the distribution and abundance of insect species present on earth (Sykes, 2009).

In the present study local distribution data of species was collected for high accuracy of species distribution modelling. The AUC values from ROC curve was used to evaluate the accuracy of model, the closer the value of AUC curve is to 1 the better the performance of maxent model (Breiner et al., 2015). The AUC values observed in present study was found to be in acceptable range i.e. >0.9 making them highly accurate models. Among the environmental variables used in Maxent species distribution modelling of *S. litura*, Bio6 (Minimum temperature of coldest month) played a major role. The plots of prediction model reflected the dependency of distribution of species on Bio6 variable, with Jackknife test depicting similar results. According to Chattopadhyay et al. (2019) outbreak of *S. litura* was observed at temperature between 21-27°C and RH above 90%. This could be related to the insect collected from Pantnagar, since the insects collected in the month of May were not able to survive due to possibly high temperature and absence of optimum RH required for the insect and so, is the reason for survival of *S. litura* in September since the insect was getting optimum temperature and RH at that time of the year in Pantnagar (Fig. 1).

The correlation studies of infestation scales were done with both temperature and RH and a correlation coefficient of 0.467 was observed between RH and infestation scale, similarly a correlation coefficient of 0.323 was found between infestation scale and temperature. Ratner (2009) classified the strength of correlation coefficient into 6 broad categories and the correlation values of *S. litura* with both temperature and

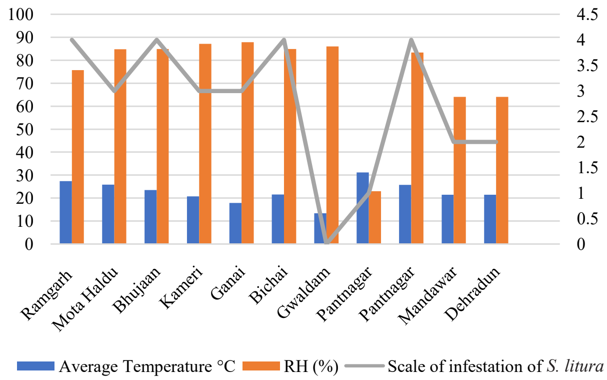

Fig. 1. Relation of infestation with temperature and humidity

RH indicates a moderate positive linear relationship, indicating the requirement of optimum RH and temperature for survival of *S. litura*. The results showed that the growth and distribution of *S. litura* is dependent on temperature and change in temperature will affect the shift in species suitable areas (Stange and Ayres, 2010; Khan et al., 2019). Due to warming of climate, mortality due to extreme cold in winters in insects is reduced (Lombardero, 2000) and climate warming affects dispersal of insect species population directly (Bale et al., 2002). Warm climate generally helps in spreading of insects mid- to high latitudes which caused a major shift in insect dispersal over past half century (Stange and Ayres, 2010). Previous studies have shown that extreme cold in winters phenomenon has majorly affected dispersal of some insect species (Wang et al., 2020; Atwal et al., 1970; Huang et al., 2015). The shift in area from current climatic scenario (18.4%) to 48.27% in 2030s RCP 2.6, 49.72% in RCP 4.5 and 52.53% in RCP 8.5 to northward direction was observed in study. Some of the previous studies are consistent with our simulation predicting more northerly distribution of insect species with climate change in future climatic conditions (Wang et al., 2015), and wider potential distribution of *S. litura* under various climatic conditions (Yoon and Lee, 2021). The results of present study provide the basis for assessment of potential distribution of polyphagous pest *S. litura* in North-Western Himalayan region and could be used formulating management policies to vulnerable potential areas of region. The study indicated that the potential distribution of *S. litura* is dependent on temperature and due to warming of climate in future the insect could increase its activity area, and it is important to design management techniques for effective measure and prevention of further spread. Risk analysis by effective and efficient monitoring system is recommended for potential distribution assessment and precise management practices of pest.

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Dr Rashmi Joshi is the main author and did complete research with Sudha Mathpal in field study, under guidance and mentorship of Dr Neeta Gaur.

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