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SHORT COMMUNICATION

Future of Rice Yellow Stem Borer *Scirpophaga incertulas* (Walker) Under Changing Climate

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Abstract Status of rice yellow stem borer (YSB) during *kharif* was predicted for future periods (2030, 2050, 2080 and 2100) under A1B emission scenario of changing climate and compared with past (2011) and current (2016) periods for six rice-growing agro-climatic locations in India. Location-specific predictions for YSB severity (high, moderate and low) were developed combining criteria on weather variables and population levels of YSB adults in light trap based on rules of prediction. Validation of weather-based prediction rules on YSB for *kharif* (22–44 standard meteorological weeks) of 2011–2016 indicated varying degrees of accuracies for locations [> 80% for Ludhiana (Punjab); > 70% for Raipur (Chhattisgarh) and Karjat (Maharashtra)] and seasons [35–61% at Chinsurah (West Bengal); 17–87% at Mandya (Karnataka) and 35–100% at Aduthurai (Tamil Nadu)]. Prediction accuracies for 2016 were > 80% at all locations, but 48% at Chinsurah (West Bengal). Decline in 'high severity' during 2016 (the present period) over 2011(the past period) was noted at Raipur (CG) and Mandya (KA). 'Low severity' of YSB at present over past periods was documented at Chinsurah (WB) and Raipur (CG) with no changes at Karjat (MH) and Aduthurai (TN). Predicted YSB severity levels for future periods, viz. 2030, 2050, 2080 and 2100 using the temperature and rainfall projections of emission scenario of A1B indicated an increasing moderate severity of YSB at Ludhiana and Chinsurah in 2050 and the absence of high severity among five locations except Chinsurah in 2100. Increase in moderate and high severity levels between 2030 and 2050 followed by its decline in 2080–2100 at Mandya and the lowest severity almost throughout all periods at Aduthurai were the projected YSB status. While extreme weather events, especially high and unseasonal rains and associated fluctuating weather conditions can have negative impact on YSB severity, the future projected status of YSB implies its lesser significance over the present period of 2016 with rare outbreaks in the context of changing climate.

Keywords Yellow stem borer · Light trap · Prediction rules · Climate change · Future status

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Introduction

Vulnerability of natural and man-made agro-ecosystems to the challenging and happening phenomenon of climate change is a reality, and rice ecosystems are not exceptions. In India, rice is grown in varied climatic zones and eco-regions depending upon temperature, soil types, water availability, rainfall and other climatic conditions with a single crop to three crops taken up per year. Eighty four per cent of 42.7 million hectares cultivates rice during *kharif* with sowings taken up between June and July [1]. An estimated 25% yield loss occurs in rice production due to insect pests despite 28% of pesticide use in India [2]. Crop–insect pest–environment interactions are a continuum over time and space, and the incidences of insect pests and their bionomics on rice crop are intimately related to climatic variabilities. Among rice insects, yellow stem borer (YSB) (*Scirpophaga incertulas* (Walker) (Pyralidae; Lepidoptera) is a regular and key pest of rice distributed across all agro-climatic zones of India. Larvae of YSB feed on central shoots of rice tillers during vegetative stage and cause 'dead heart' and 'white ear' results if feeding coincides with panicle initiation stage. YSB on rice gains top priority across rice-growing regions of India as its damage is at both vegetative and reproductive crop stages and causes yield losses to an extent of 27–34% every year [3]. Light trap catches represent the abundance of insect pests and severity of anticipated damage in rice ecosystems, and YSB moth catches in light traps are often used as monitoring tool throughout the year.

Weather plays a dominant role in influencing all agricultural operations including pest management adopted by the farmers. Congenial weather conditions favour higher incidence of insect pests including YSB as its bionomics is intimately related to prevailing weather. Establishing relation between light trap catches of YSB and weather provides necessary information on timing and abundance of its population. Short-term forecasts for YSB using light trap catches and weather parameters attempted in India using monthly seasonal indices of abiotic factors [4], day degree and regression models [5] during last decade are available with their field use limited at present. Therefore, it becomes necessary to develop weather-based models including the data sets of the recent past to predict YSB severity for use in its forewarning. Climate change is a happening phenomenon everywhere, and their influence on insect pests are inevitable sooner or later. Documented evidences of changing weather over onset, peak and severity of insect pests across crops generated through laboratory experiments and field data in India are available [6]. Therefore, it is also pertinent to assess the future status of YSB using the developed models and climatic projections towards strategic planning on management of YSB.

Development of Weather-Based Predictions for YSB

Six rice-growing locations from different agro-ecological regions representing various agro-climate zones and year round daily catches of YSB in light traps (Chinsurah type) over past periods (Table 1) formed the basis for development of location-specific weather-based predictions. The data assembled were processed to obtain YSB numbers/trap/standard meteorological week (SMW). Weather variables, viz. maximum temperature (°C) [Tmax], minimum temperature (°C) [Tmin], morning [RHI] and evening [RHII] relative humidity (%), rainfall (mm) [RF] and sunshine hours (h/day) [SSH] on SMW basis of specified locations, were collected from respective meteorological observatories. Data sets of YSB catches in light trap (nos/trap/week) and weather variables (5 nos) pertaining to *kharif* (22-44 SMW) were used for development of rule-based location-specific predictions using heuristic approach.

Rule-based predictions are based on the iterative and exploratory analysis not guaranteed to be optimal or perfect, but practical, simple and sufficient for immediate goals. While variability in data sets over years of YSB population was considered for development of categories of pest severity levels, congenial conditions of weather in respect of YSB [4, 5, 7, 8] were used to formulate weather-based criteria for each location. Steps involved in the formulation of the weather-based pest predictions were: (1) classification of pest severity levels into categories of low, moderate and high, (2) development of weather-based criteria through comparison of weather variables *vis a vis* insect population accounting for congenial weather wherein weather factors lagged by one week of respective YSB data were accounted, (3) development of rules combining weather-based criteria (step 2) and pest severity levels (step 1) for use in prediction and (4) validation of the developed weather-based prediction. Range of values for category of pest severity, and weather variables constituting criteria in respect of locations are furnished in Table 2. Prediction accuracy was worked out for the period of *kharif* (22–44 SMW) season based on week-wise forecasts. Satisfying more than three, three and less than three out of five weather-based criteria constituted rule of prediction for YSB severity of high, moderate and low, respectively, across all locations.

$$\text{Prediction accuracy } (\%) = \text{Number of weeks with correct prediction} / \text{Total number of weeks} * 100$$

Validation of YSB Predictions

Prediction accuracy of weather-based prediction of YSB severity across 2011–2016 *kharif* seasons varied from the lowest of 17.4 to a perfect 100%. Validations indicated that prediction accuracy varied across the seasons for the same location (Table 3).

Table 1 Study locations and periods of data sets of YSB and weather used for development of YSB prediction

Location	GPS coordinates	Agro-climate zone	Agro-ecological region	Data sets of YSB and weather used
Ludhiana—Punjab (PB)	30°54′N, 75°48′E	Trans-Gangetic Plains	Northern plain and central highland + Aravalis, hot semi-arid eco-region	2011–2014
Chinsurah—West Bengal (WB)	22°91′N, 82°E	Lower Gangetic Plains	Bengal and Assam plain hot sub-humid to humid to per humid eco-region	2011–2014
Raipur—Chhattisgarh (CG)	21°30′N, 82°0′E	Eastern Plateau and Hills	Eastern plateau hot semi-humid eco-region	2000–2010
Karjat—Maharashtra (MH)	18°91′N, 73°33′E	West Coast Plains and Ghat	Western ghat and coastal plain hot humid per humid eco-region	2011–2014
Mandya—Karnataka (KA)	12°52′N, 76°90′E	Southern Plateau and Hills	Eastern ghat, TN upland and Deccan plateau hot semi-arid eco-region	2011–2014
Aduthurai—Tamil Nadu (TN)	11°N, 79°3′E	East Coast Plains and Hills	Eastern coastal plain, hot sub-humid to semi-arid eco-region	2000–2010

Table 2 Levels of pest severity and weather criteria predicting YSB severity

Location	Pest severity (No. of YSB moths/trap/week)	Weather criteria
Ludhiana (PB)	High (> 100), moderate (50–100), low (< 50)	T_{max} (30–33), T_{min} (23–24), RHI (85–90), RHII (60–70) and RF (< 10)
Chinsurah (WB)	High (> 200), moderate (100–200), low (< 100)	T_{max} (33–36), T_{min} (22–28) RHI (89–92), RF ($\leq$ 10) and SSH (5–9)
Raipur (CG)	High (> 1000), moderate(100–1000), low (< 100)	T_{max} (31–34), T_{min} (22–23), RHI (89–92%), RF (0–10) and SSH (6–9)
Karjat (MH)	High (> 100), moderate (50–100), low (< 50)	T_{max} (30–32), T_{min} (23–24), RHI (94–95), RHII (70–78) and RF (< 10)
Mandya (KA)	High (> 100), moderate (50–100), low (< 50)	T_{max} (30–32), T_{min} (21–22), RHI (90–94), RHII (45–55) and RF (< 10)
Aduthurai (TN)	High (> 200), moderate (100–200), low (< 100)	T_{max} (30–32) T_{min} (20–22), RHI (90–93), RF (< 10) and SSH (8–9)

Table 3 Validation of YSB predictions

Location	Prediction accuracy (%) for *kharif* seasons					
	2011	2012	2013	2014	2015	2016
Ludhiana (PB)	91.3	95.6	82.6	82.6	95.7	87.0
Chinsurah (WB)	52.2	56.5	34.8	52.2	60.9	47.8
Raipur (CG)	87.0	95.6	78.3	82.6	70.0	91.3
Karjat (MH)	87.0	73.9	82.6	87.0	86.4	100
Mandya (KA)	39.1	17.4	82.6	86.9	73.9	87.0
Aduthurai (TN)	47.8	34.8	100	65.2	95.7	100

Greater than 80% accuracy of forecast was observed at Ludhiana (PB) that grows rice only during *kharif*. Accuracies were constantly above 70% for all years for Raipur and Karjat wherein cropping systems have larger areas under rice not only during *kharif*. Chinsurah, Mandya and Aduthurai had highly fluctuating prediction accuracies despite consecutive seasons of rice cultivation due to extremes of weather. Accuracies at Mandya (KA) and Aduthurai (TN) were better for 2013, 2014 and 2015 seasons over 2011 and 2012. Extreme weather event of Neelam cyclone during October 2012 at Aduthurai (TN) [9] and highly reduced rainfall over normal during pre-monsoon periods [9] of 2011 and 2012 at Mandya (KA) reducing the YSB could have the reasons for reduced prediction accuracies. Frequent intra-season variability of all weather parameters such as maximum temperature and minimum temperature, relative humidity and rainfall observed during *kharif* [10] and their differential impact on YSB could be the reason for moderate to lower prediction accuracies observed consistently with Chinsurah (WB).

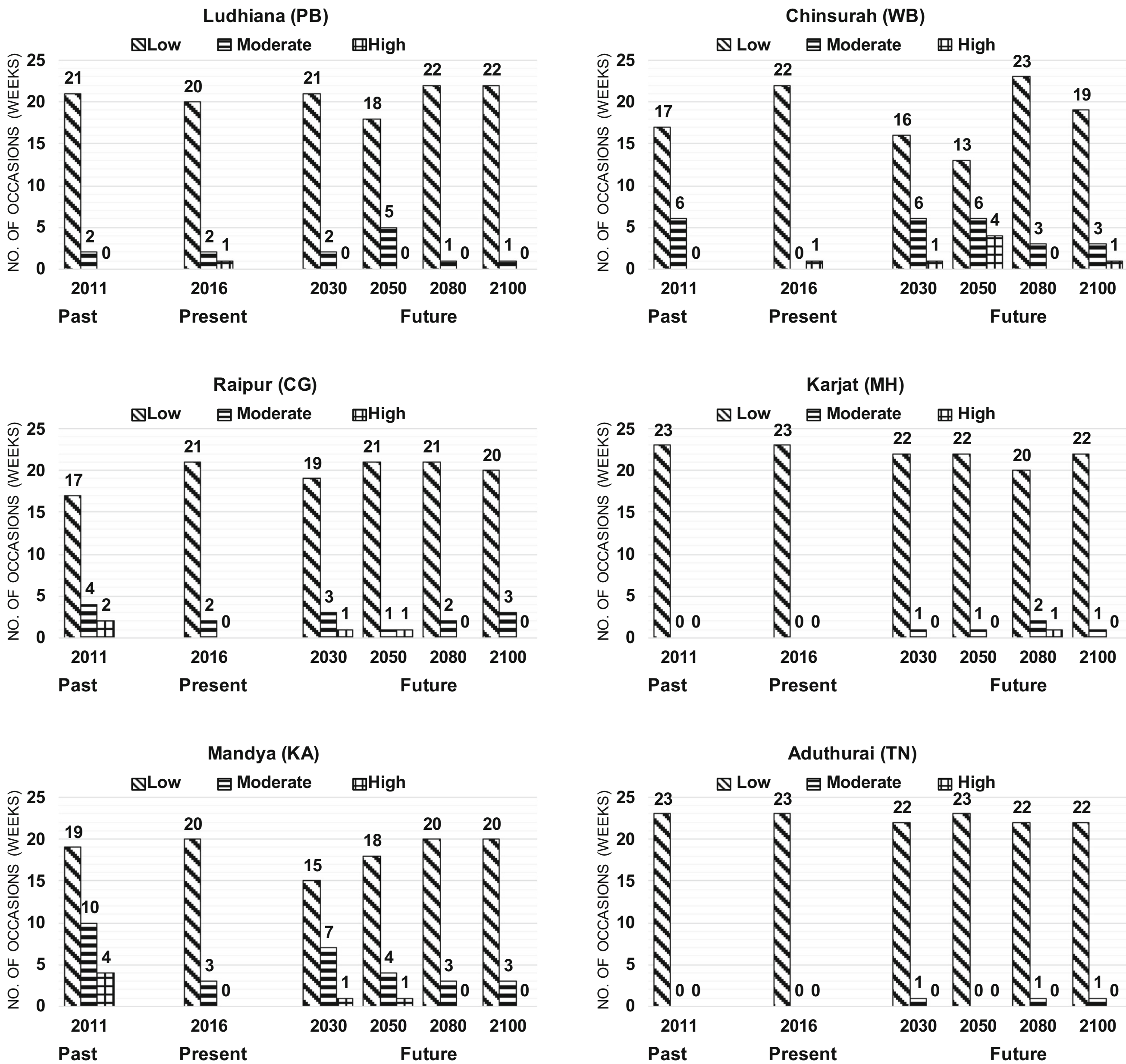

Fig. 1 The past, current and future status of YSB severity

Future Status of YSB

Projections of maximum temperature and minimum temperature besides rainfall derived for future years at a resolution of 50 × 50 km grid for emission scenario of A1B of PRECIS were obtained for study locations from Central Research Institute for Dryland Agriculture, Hyderabad, based on simulated climate projections for India [11]. Projected data relevant to four future periods, viz. 2030, 2050, 2080 and 2100, calculated on standard meteorological week (SMW) basis were used to predict future scenarios of YSB severity on SMW basis for a total of 23 SMWs of *kharif* season (22–44 SMWs). Number of weeks with predicted severity of YSB into categories of high, moderate and low in respect of four future periods in respect of study locations is presented in Fig. 1 along with 2011(past) and 2016 (present) periods.

Comparison of the predicted severity levels for the past (2011), present (2016) and four different future seasons, viz. 2030, 2050, 2080 and 2100, using the temperature and rainfall projections of emission scenario of A1B for six locations indicated an increasing moderate severity of YSB at Ludhiana and Chinsurah in 2050 and the absence of high severity levels among five locations except Chinsurah in 2100. Increase in moderate and high severity levels of YSB between 2030 and 2050 followed by its decline in

2080–2100 at Mandya (KA) and the lowest severity almost through all periods at Aduthurai (TN) were projected. Future projections of YSB imply lesser significance of YSB in context of changing climate with rare outbreaks expected. Under these circumstances, it is only prudent to monitor YSB as in present times and use management interventions based on economic threshold levels [12]. It can also be said that extreme weather events, especially high and unseasonal rains and highly fluctuating weather conditions during any given season, can have a negative impact on YSB severity. Nevertheless, the use of weather-based predictions of YSB developed in the present study should serve as a forewarning tool for use by researchers, extension personnel and rice growers of seven different locations of India. Issue of 'pest alerts' at times of 'moderate and high severity' predictions based on weather criteria would strengthen effective YSB management within framework of integrated pest management on rice.

Way Forward

The present paper assesses the impact of change in climatic variables on futuristic scenario of YSB. However, changes in multitude of factors such as cropping system, varietal scenario and production practices at macro-level, and inter-specific competitions and adaptive adjustments by insects in general and YSB in particular on ecological and evolutionary scales would decide ultimately its abundance and hence the severity. Climatic projections for future are available nowadays based on representative concentration pathways (RCPs), and their use to further ascertain future status of YSB would be the next logical step.

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