AATCC Review

18 July 2024: Received
19 August 2024: Revised
26 September 2024: Accepted
28 October 2024: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Weather-based prediction module: A promising tool for *Spodoptera litura* anticipation in groundnut?

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ABSTRACT

Spodoptera litura has been causing considerable damage to groundnut and other crops across India. Anticipation of pest incidence using a prediction module under changing climate is need of the hour. The Spodoptera litura male moth caught by sex pheromone trap from 1991-20 (30 years) during kharif season is considered for the study. The 30 years of data clearly indicated that moths trapped were concentrated in 34th and 35th SMW, which falls during the second fortnight of August and the first week of September. There was steep decline in the number of moths trapped from 2015 onwards indicating a consistent decrease in Spodoptera incidence during kharif at Dharwad despite of normal rainfall and other weather factors. The multiple regression model fitted had multicollinearity of independent variables. Stepwise regression, Morning RH was found to be the major deciding factor of Spodoptera population. Finally, simple linear regression model was fitted and the predicted trap catch data was validated with actuals for four consecutive kharif seasons starting from 2017. However, the predicted was found to be far higher than actual number of moths trapped during respective years. The presentanalysis clearly indicated need for a better understanding the influence of biotic and abiotic factors on Spodoptera under field conditions.

Keywords: *Spodoptera litura, pheromone trap, male moth, regression. prediction*

Abbreviations: SMW= standard meteorological week,
ICRISAT=International Crop Research Institute for Semi-arid Tropics
MARS = Main Agricultural Research Station
^{0}C = Degree centigrade , RH= Relative humidity

INTRODUCTION

India is one of the largest producers of oilseeds in the world and oilseed occupies an important position in the Indian agricultural economy. Groundnut is grown on 26.4 million ha. worldwide with a total production of 37.1 million metric ton and an average productivity of 1.4 metric t/ha. Over 100 countries grow groundnut worldwide and developing countries constitute 97% of the global area and 94% of the global production of this crop.The major groundnut-producing countries in the world are India, China, Nigeria, Senegal, Sudan, Burma and the United States of America. Out of the total area of 18.9 million hectares and the total production of 17.8 million tons in the world, these countries account for about 69 percent of the area and 70 percent of the production. India occupies the first place, both in regard to the area and the production in the world. Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka are the leading groundnut-growing states in India.

A polyphagous insect pest, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae), has been causing immense damage to various crops including groundnuts across India. This insect has been considered as a pest of national importance due to its wide host range and the development of proper monitoring system is a pre-requisite to formulate an integrated management practice (Ranga Rao *et al*., 2011). The severe infestation can cause 30 to 40 percent loss in pod formation. A pod loss of 66.6 percent in groundnut at Dharwad has been reported (Kulkarni, 1989). Further, studies at ICRISAT indicated that groundnut crops is vulnerable to damage and defoliation up to 50 days after emergence, which needs to be contended. However, at a later stage of the crop, when defoliation is severe and more than 50 per cent there is a need for immediate protection measures to avoid yield loss. Also, stated that total crop failures were reported despite of protection measures (Wightman and Ranga Rao, 1993). Field studies have shown that damage by single larvae per groundnut plant at seedling and flowering stage could cause a significant yield loss of 25.8 and19 percent, respectively (Dhir *et al.,* 1992). Field studies at Orissa, India showed that one larva of *S. litura* per groundnut plant at the seedling and flowering stages could cause about 54.7 and 49.1 per cent leaf area and reduced pod yield by 25.8 and 19 per cent, respectively. At flowering, one larva per plant consumed 49.1 per cent leaf area and reduced the yield by 19 per cent. At pegging, one larva per plant consumed about 38.8 per cent leaf area and resulted in a yield loss of 5.7 per cent. The pest has already developed resistance to insecticides such as organochlorines (endosulfan), organophosphates (chlorpyrifos, phoxim, quinalphos, profenofos), carbamates (methomyl, thiodicarb) and pyrethroids (bifenthrin, cyfluthrin) (Mushtaq *et al*., 2007).

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DOI: https://doi.org/10.21276/AATCCReview.2024.12.04.152

The impact of the changing climate on agriculture are being witnessed all over the world and there are many reports about its influence on the insect population too. A significant increase in temperature has been witnessed during the last three decades (Stern, 2007). Climate change projections made for India indicate an overall increase in temperature from 2 to 4 °C with no substantial change in precipitation quantity by 2100 (Krishnakumar *et al*., 2011). The incidence of insect pests and their population density is driven by various environmental factors, mainly temperature, humidity, and precipitation. The pheromone traps offer one of the best sampling tools for flying adult insects and is commonly adopted for pest surveillance program (Prasanna Kumar, 2011). Monitoring *S. litura* through sex pheromone traps is an important prerequisite for effective management even during future climate change scenarios. Information obtained from pheromone trap collections in any area for a fairly long period of can be used for thedevelopment of models to predict seasonal pest incidence. Several factors (including nature of trap) influence insect activity and trap performance which is confounding in nature, the role of environmental factors is crucial. Several works have already been carried out about development of weather-based linear and non-linear prediction modules (Agarwal and Mehata,2007). The *S .litura* male moths trapped in sex pheromone traps was studied earlier in different crop ecosystems. The male moth trap catches started from 19^{th}SMW and continued up to 43^{rd}SMW in vegetable ecosystem (tomato and cauliflower). There was a significant positive correlation with maximum and minimum temperatures (r = 0.813 and r =0.805, respectively) and a number of moths trapped per week (Md. Monobrulla *et al.,* 2007). The present study was conducted (i) to quantify the relationship between weather factors and sex pheromone trap male moth catches and (ii) also to identify the best fit model to predict the future *S. litura*scenario in changing climate.

MATERIAL AND METHODS

The *S. litura* male moth caught in sex pheromone trap from 1990 to 2020 (30 years) during *kharif* season is considered for analysis. A weekly total was obtained from daily average catches of male moths in three pheromone traps located exclusively in groundnut fields with a distance of 100 m between traps located at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The lures were changed once in every 15 days throughout the season. The sleeve traps with commercially available *S.litura* pheromone (Z,E)-9,11-tetradecadienylacetate and (Z,E)-9,12-tetradecadienyl (at the ratio of 10:1) and the quantity of the chemical present was 0.84 mg per lure. Male moths trapped from 26 to 42 standard meteorological week (=SMW) is considered for analysis.

The average weekly total number of moths trapped and the average weather parameters of the corresponding SMW are considered for analysis. The weather variables such as maximum and minimum temperature, morning and evening relative humidity and total weekly rainfall were considered as independent variables.

***Statistical Analysis*:** The pheromone trap catch data from 1991 to 2020 was considered for the study. The data is compiled and trap catches for the corresponding SMW (Standard meteorological week) is worked out collection for correlation with corresponding weather parameters of SMW. The average data for the 30 years is further subjected to correlation studies with average weather parameters of corresponding SMW. Once after proving the existence of correlation, the data was subjected to regression. Before performing regression analysis, the trap catch data was subjected to log transformation to reduce the multiplicative deviations and to make it more reliable for analysis. The data was first subjected to multiple linear regression using Rainfall, Maximum and Minimum temperature, Morning and Evening Relative Humidity as independent variables, and trap catch data as dependent variable to find out the relation and to fit a prediction model. Further significance of the regression was tested before proceeding. Once after checking the significance multicollinearity diagnosis was performed to identify the presence or absence of multicollinearity among independent variables. The multicollinearity between the independent factors was identified by looking at the VIF and condition index of eigenvalues. The variables were identifiedwhich were multicollinear. Further, step wise regression was performed to identify the contribution of each independent factor in deciding dependent factor, trap catch. However, among the dependent variables only morning RH found to be contributing significantly and by taking morning relative humidity a simple linear regression was fitted and prediction results were compared with actual.

RESULTS AND DISCUSSION

The pheromone trap catches of *Spodoptera litura* were studied from 1991 to 2020 at MARS, Dharwad. The trap catches and weather parameters starting from 26^{th} SMW (from June 25^{th} to 1^{st}July) to 44^{th} SMW (12^{th} to 18^{th} November) was considered for analysis which represents the *kharif* season. The corresponding weather data collected from MARS, Dharwad was used for analysis and comparison. The time of peak trap catches of *Spodoptera* male moths from the year 1991 to 2020 falls in between 29^{th} to 39^{th} SMW and further, it was recorded at 34^{th} SMW in the majority years (Table 1a & 1b and Fig. 1).

Table 1a. Pheromone trap catches of Spodoptera litura male moth (1991-2020)

SMW	Year														
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
26	74	171	0	332	18	90	0	0	0	0	0	0	0	10	0
27	72	105	105	482	16	601	64	434	32	9	0	71	0	0	0
28	64	30	98	88	26	324	297	951	37	5	0	148	0	4	0
29	39	37	49	113	58	121	**316**	**1849**	48	3	33	**153**	3	21	5
30	24	53	70	57	61	60	286	1580	15	89	0	97	7	13	20
31	96	52	99	454	85	113	91	658	29	324	4	46	10	8	14
32	**238**	105	264	1601	108	138	127	602	52	161	2	31	17	18	8
33	88	174	202	**2720**	159	103	204	777	66	181	3	36	123	41	18
34	78	159	269	2714	**311**	149	202	649	83	25	4	38	**196**	533	**561**
35	114	290	245	2086	308	141	151	457	90	84	14	134	53	609	475
36	123	**343**	**410**	1272	184	157	178	66	115	**415**	**34**	60	79	**764**	530
37	116	134	399	1659	196	**432**	111	156	127	110	14	45	116	502	476

38	157	140	462	72	129	260	53	108	152	215	25	42	93	242	411
39	93	131	375	0	19	310	129	35	**176**	43	31	20	65	103	364
40	104	38	161	0	99	399	102	0	167	0	17	8	47	120	350
41	28	45	49	0	77	414	7	0	159	0	17	0	38	51	170
42	10	0	22	0	0	288	0	0	54	0	14	0	19	72	142
43	0	0	7	0	0	198	0	0	0	0	0	0	24	75	0
44	0	0	6	0	0	0	0	0	0	0	0	0	10	0	0

Table 1b. Pheromone trap catches of Spodoptera litura male moth (1991-2020)

SMW	**Year**														
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
26	103	0	25	12	36	9	28	0	0	0	33	9	0	3	36
27	102	130	132	9.3	127	17	45	0	0	0	42	13	7	4	70
28	91	65	51	59	206	65	62	0	6	3	24	28	17	4	83
29	106	56	143	87	324	128	93	0	9	16	25	32	26	4	162
30	135	68	109	111	821	132	138	5	11	27	20	48	39	0	196
31	197	57	103	210	744	111	139	37	30	41	17	113	97	1	223
32	216	13	129	883	884	261	220	78	61	56	21	171	158	0	217
33	234	476	138	1032	634	355	374	45	89	79	5	89	71	0	164
34	211	839	102	1375	623	378	648	56	105	645	4	69	60	0	130
35	582	550	143	819	865	894	624	85	126	424	0	54	46	1	82
36	691	688	168	383	420	380	382	39	181	314	0	45	45	0	49
37	769	482	143	164	261	284	297	18	263	206	0	33	28	1	36
38	884	127	111	242	219	233	240	30	218	138	0	21	19	1	27
39	567	88	96	171	8	207	151	146	174	91	0	12	5	0	19
40	608	56	139	150	35	135	153	188	77	59	0	7	0	0	6
41	383	0	96	9	21	109	79	9	23	21	0	3	0	0	4
42	0	4	0	9	28	129	28	0	6	7	0	0	0	0	0
43	0	0	0	10	16	76	13	0	6	0	0	0	0	0	0
44	0	0	0	12	2	13	2	0	6	0	0	0	0	0	0

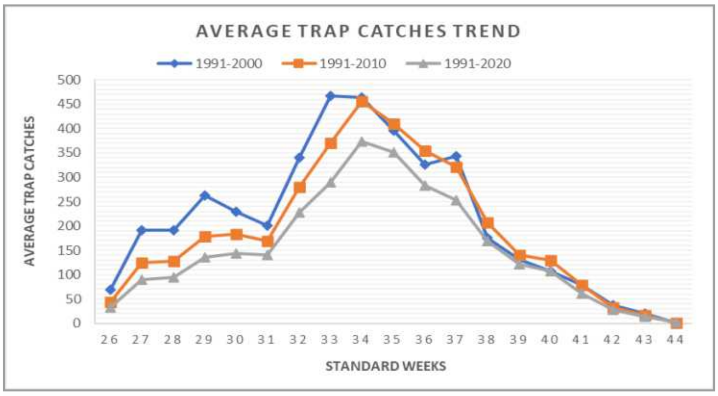

Fig 1. Trap catch trend (1991 to 2020)

Fig 2. Trap catch trend with 10 years interval

The average peak trap catches with 10 years interval starting from 1991 to 2000, 2001 to 2010 and 2011 to 2020 were averaged to 34 and 35th SMW (Fig. 2). There was scanty rainfall from 2001 to 2003 which led to poor crop stand in the region including MARS, Dharwad, lower pest incidence and also lower number of trap catches. This indicated the importance of proper rainfall which ultimately ensure proper host plant stand and also the Relative Humidity. There was sharp fall in the number of moths trapped especially from 2015 onwards despite of proper rainfall received and prevailing of required Relative Humidity and other weather factors. This indicated that *Spodoptera* population is decreasing consistently during *kharif* at Dharwad. The change in the incidence level was obvious and visible. Similar remarks were also opined by Duraimurgan 2018, who stated that year to year variation in the abundance of *S. litura* could not only be due to response to the prevailed weather but could also be due to the abundance of host crops within the regional agro-ecosystem.

There was hardly any change in the temperature (Maximum & Minimum) over a period of 30 years from 26th to 44th SMW at Dharwad (Table 2).

However, there was a steady decrease in both morning and evening relative humidity over a period of 30 years. The decrease in humidity was very much evident after 2000 onwards. However total average rainfall ranged about 500 mm during the period with a lot of fluctuations. The least rainfall of 101.2 mm was recorded during the year 2003 and that of the highest was 1165.6 mm was recorded during the year 2019. However, the thirty years average total was 515.45 mm during 26th to 44th SMW. But there was considerable change inrainfall pattern and distribution. The rainfall earlier was persistent and definite and presently it is erratic and doubtful. Especially at the beginning of the season from 26th to 30th SMW, the quantity received is noticeably higher up to 2000 and reduced then afterwards. There used to be continuous drizzling at the beginning of the season which is absolutely not prevailing in recent days. However, the relation with rainfall was not significant at any interval from 1991 up to 2020. The pattern and distribution instead of quantity of rainfall received during the period may be an important factor in deciding *Spodoptera* population during the season at Dharwad and in the absence of any such published report it will be difficult to discuss further. It was opined that in general, climatic changes involving altered precipitation patterns and regimes greatly influence the plant-insect herbivory interaction, and multi-trophic interactions and exhibit differential growth and development rate, thus mitigating the fitness of a phytophagous insect (Jamieson *et al.*, 2012).

The morning and evening relative humidity exhibited a positive and significant relation with pheromone trap catch consistently at 15, 20, 25 and 30 years since 1991. The considerable decrease in the Relative Humidity over the years may also be an important reason for the decline in the *Spodoptera* population. Until the year 2000, morning RH was 90 per cent and above, from 26^{th} to 44^{th} SMW. The changed pattern of rainfall may be a reason which resulted in reduced RH. The delay in the commencement of rainy season followed by reduced initial intensity coupled with irregular distribution might have resulted in a reduction of relative humidity. The reduced relative humidity may not favor the *Spodoptera* population. The relative humidity ranging from 89 to 92 per cent supported the higher population and growth of *Spodoptera* as reported by Selvaraj *et al.* (2010) and by Shahzad *et al.* (2014). There existed a significant negative correlation between trap catches and maximum temperature at an average of 10, 15, 20, 25 and 30 years (Table 3) since 1991. A negative relation with temperature was also reported in the past (Naresh *et al.*, 2017, Shahzad *et al.*, 2014, Selvaraj *et al.*, 2010).

Table 2. Prevailed weather parameters at MARS, Dharwad during kharif season (1991 to 2020)

SMW	1991-1995 (5 years)					1991-2020 (30 years)				
	Maximum Temp	Minimum Temp	Morning RH	Evening RH	Rainfall	Maximum Temp	Minimum Temp	Morning RH	Evening RH	Rainfall
26	28.40	21.02	91	76	28	28.10	21.04	91	76	27
27	27.90	20.77	93	78	12	27.58	20.88	91	77	21
28	26.36	20.78	94	87	54	27.23	20.86	91	79	32
29	25.55	20.42	94	88	57	26.83	20.81	92	81	35
30	25.49	20.72	93	89	38	26.60	20.78	92	81	32
31	25.50	20.7	91	88	26	26.47	20.62	91	81	41
32	26.93	20.36	92	83	14	26.38	20.46	92	80	39
33	26.22	20.48	92	86	26	26.66	20.44	91	78	22
34	26.95	20.37	93	84	15	27.43	20.4	91	77	17
35	26.00	20.22	92	88	28	27.37	20.29	91	78	20
36	26.74	20.03	92	84	13	27.85	20.11	90	76	21
37	28.63	19.56	91	76	9	28.47	20.16	90	73	18
38	29.25	19.52	91	73	25	28.40	19.86	89	72	29
39	29.76	20.17	91	71	15	29.13	20.09	89	69	41
40	29.48	20.09	92	70	76	29.38	20.26	89	69	38
41	28.87	20.67	92	75	12	29.71	20.34	88	65	19
42	28.62	19.77	91	74	57	29.74	19.53	84	62	41
43	29.97	19.39	91	69	25	29.65	18.79	81	59	18
44	28.95	18.1	91	75	2	29.67	17.97	81	59	4

Table 3. Correlation between weather parameters and pheromone trap catches

Climatic factors	Period from 1991 to 2020					
	1991-1995 (5 years)	1991-2000 (10 years)	1991-2005 (15 years)	1991-2010 (20 years)	1991-2015 (25 years)	1991-2020 (30 years)
Temperature (Max) ^{0}C	-0.37	-0.65	-0.60	-0.55	-0.51	-0.55
Temperature (Min) ^{0}C	0.12	0.38	0.29	0.30	0.28	0.32
Relative Humidity (Morning) (%)	0.05	0.43	0.57	0.60	0.57	0.59
Relative Humidity (Evening) (%)	0.42	0.71	0.64	0.59	0.55	0.59
Rainfall (mm)	-0.35	-0.31	-0.26	-0.21	-0.17	-0.12

After considering the presence of significant relations, the data was subjected to regression analysis. A multiple linear regression was fitted and the R^2 value was 0.705 it was significant (Table 4). The result indicates that five independent variables together contribute about 70.5 percent of trap catch collection (Table 4). The fitted regression model exhibited an equation that stated, trap catches = -5.953 - 0.36 X Max Temperature + 0.005 X Rainfall - 0.253 X Min Temperature - 0.137 X Evening Relative Humidity + 0.373* X Morning Relative Humidity. However, the VIF value was more than 20 for Maximum temperature, Evening and Morning RH indicating the presence of multicollinearity with all these three independent factors. However, the results also indicated the significant contribution of Morning Relative humidity (Table 5) in deciding trap catches**.** It was stated that Morning and Evening RH had a positive correlation with pest population on one or two weeks prior to the incidence. Further, reported that maximum and minimum temperatures ranging from 26-27^0 C and 21-22^0 C and morning RH of 90 per cent, a week prior to incidence are critical weather parameters causing the outbreak of *S. litura* in soybean (Chattopadhyay *et al.*, 2019).

Table 4. Multiple regression model summary for prediction of Spodoptera litura

Model Summary										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	0.839^a	0.705	0.591	0.36381	0.705	6.202	5	13	0.004	1.581

The regression value the per cent contribution of five variables together is 70.5 %. Model is significant

Table 5. Multiple regression model coefficients

Coefficients									
	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Partial	Part	Collinearity Statistics Tolerance	VIF
(Constant)	-5.953	9.768		-0.609	0.553					
Max T	-0.367	0.394	-0.764	-0.932	0.368	-0.617	-0.250	-0.140	0.034	29.55
Rainfall	0.005	0.010	0.080	0.464	0.650	0.292	0.128	0.070	0.768	1.30
Min T	-0.253	0.289	-0.339	-0.874	0.398	0.692	-0.236	-0.132	0.151	6.64
Evening RH	-0.137	0.117	-1.771	-1.172	0.262	0.729	-0.309	-0.177	0.010	100.48
Morning RH	0.373	0.163	2.150	2.293	0.039	0.808	0.537	0.346	0.026	38.67

The data was subjected to collinearity diagnostics using condition correlation index which indicated the presence of multi-collinearity in maximum Temperature (0.90) and evening Relative humidity (0.96) as the conditional correlation value equals or higher than 0.9 (Table 6). Further, data was subjected to stepwise regression which eliminated all other variables and kept only the morning Relative Humidity as significant and R^2 value worked out to be 65.2 per cent. A simple linear regression equation is fitted as Trap catches= -10.475 + 0.140 X Morning RH (Table 7) for predictionof moths to be trapped. Similar analysis in relation to leafhopper, semilooper, *Spodoptera* and capsule borer on castor was undertaken using simple linear regression to fit a prediction module elsewhere in the past and found to be more accurate than other regression modules (Lakshmi and Reddy, 2015).

Table 6. Collinearity diagnostics using statistical methods

Collinearity Diagnostics									
		Eigenvalue	Condition Index	Variance Proportions (Constant)	Maximum Temp	Rainfall	Minimum Temp	Evening RH	Morning RH
Model 1	1	5.885	1.000	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.105	7.490	0.00	0.00	0.79	0.00	0.00	0.00
	3	0.010	24.122	0.00	0.00	0.03	0.00	0.00	0.00
	4	0.000	160.074	0.08	0.00	0.16	0.56	0.02	0.00
	5	0.000	312.205	0.42	0.08	0.02	0.43	0.00	0.23
	6	0.000	588.922	0.49	0.92	0.01	0.01	0.97	0.77

Table 7. Stepwise regression to eliminate the variables having least influence on Spodoptera litura pheromone trap catches

Model Summary [b]										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	0.808[a]	0.652	0.632	0.34525	0.652	31.868	1	17	0.000	1.771

*Trap catches = -10.475 + 0.140 * Morning RH*

Stepwise regression eliminated all other variables and kept only Morning RH significant variable. This reduced the R square value from 70.5% to 65.2%. This 5.3% variation was unexplained contribution by other 4 variables which were non-significant.

Table 8. Simple linear regression model for prediction of Spodoptera litura pheromone trap catches

Coefficients[a]									
	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Partial	Part	Collinearity Statistics Tolerance	VIF
(Constant)	-10.475	2.214		-4.731	0.000					
Morning RH	0.140	0.025	0.808	5.645	0.000	0.808	0.808	0.808	1.000	1.00

The regression equation was fitted taking average up to previous year starting from 1991 and the prediction was made for the subsequent year. The trap catch data was predicted using equation for the year 2017 to 2020 and is compared with the actual trap catch data of the corresponding year (2017 to 2020) (Fig 3). During 2017 the predicted trap catch was higher than the actual trapped. However, during 2018, 2019 and 2020, the predicted value was far higher than the actual with peaks located at different SMW (Table 9). During 2019, the actual trap catch was almost zero and that of predicted was considerable. Failure of prediction module has also been reported in the past. Magarey and Isard (2017) expressed that availability of published literature is scanty on the causes of failures associated with prediction models. One major reason may be the science seldom publishes negative reports. They also stated the possible reasons for the failure of predictions, *viz.,* Weather data from anomalous locations might have incorrect values, mismatch in the units of weather, important agronomic and/or environmental factors might not be included, pest biology and behaviour at model development locations and study location might differ and omission of critical information for decision making in the models are few other reasons. During all these years a good amount of rainfall was received and also there was favorable RH for the pest to buildup. There was no dearth of host plants and also the prevailed relative humidity was above 90 per cent due to normal rainfall during the period. Inspite of all these favorable factors *Spodoptera* population was low from 2016 to 2020. Further, incidence/outbreak of *Metarhizium rileyi* on *Spodoptera* is also playing important role in regulation of their population. The population of polyphagous pest like *Spodoptera* may also depend upon several other factors which still need to be enumerated. Further, changing climate may also be a reason.

It may be difficult to predict the population based on only the weather parameters. It would be probably better to give importance for life table analysis under field condition over the years before fitting a prediction module. Under the present prevailing changing climate and cropping pattern the use of pheromone based monitoring and subsequent first catch of moths in the trap may be more appropriate for imposing protection measures in anticipation of the pest incidence above the threshold level. Similar observations on the use of pheromone traps for monitoring of pest population and level of incidence in early detection of pest infestation and timing the insect management practices were also made in the past. Further, it was also stated that the threshold level for various pest fauna in cotton are 20 moths/trap/day for *Spodoptera litura,* 15 moths/trap/day for Spotted bollworm, 10 moths/trap/day for American bollworm and 8 moths/trap/day for pink bollworm (Nayak and Pradhan 2021).

Table 9. Comparison of predicted and actual pheromone trap catches

Standard week	Trap catches comparison for the years											
	2017			2018			2019			2020		
	Log value	**Predicted**	**Actual**	**Log value**	**Predicted**	**Actual**	**Log value**	**Predicted**	**Actual**	**Log value**	**Predicted**	**Actual**
26	2.21	163	35	2.34	221	0	2.42	**266**	3	1.94	88	36
27	2.26	180	97	2.64	**441**	7	2.13	133	4	2.74	551	70
28	2.30	200	101	2.53	335	17	2.08	121	4	2.31	203	83
29	2.38	240	143	2.27	184	26	1.22	17	4	2.63	426	162
30	2.39	**244**	150	2.17	146	39	2.08	121	0	2.46	289	196
31	2.32	207	144	1.99	97	97	2.55	**351**	1	2.53	340	**223**
32	2.35	226	239	2.03	106	**158**	2.34	221	0	2.83	668	217
33	2.22	165	313	2.34	221	71	2.00	101	0	2.87	736	164
34	2.30	202	**408**	2.05	111	60	1.55	35	0	2.88	**760**	130
35	2.27	187	386	1.99	97	46	2.42	**266**	1	2.55	351	82
36	2.16	144	312	1.61	40	45	2.41	254	0	2.27	184	49
37	2.18	151	278	1.07	12	28	2.19	153	1	2.60	399	36
38	1.97	93	186	0.93	8	19	2.06	114	1	2.74	551	27
39	1.95	90	134	1.19	15	5	1.75	56	0	2.14	138	19
40	2.02	106	119	0.35	2	0	2.36	231	0	2.17	147	6
41	1.86	73	67	1.15	14	0	2.31	202	0	2.70	500	4
42	1.26	18	31	1.10	13	0	2.47	**292**	0	2.53	340	0
43	0.86	7	16	-2.08	0	0	2.13	133	0	2.36	231	0
44	1.03	11	2	-2.00	0	0	1.63	42	0	0.08	1	0

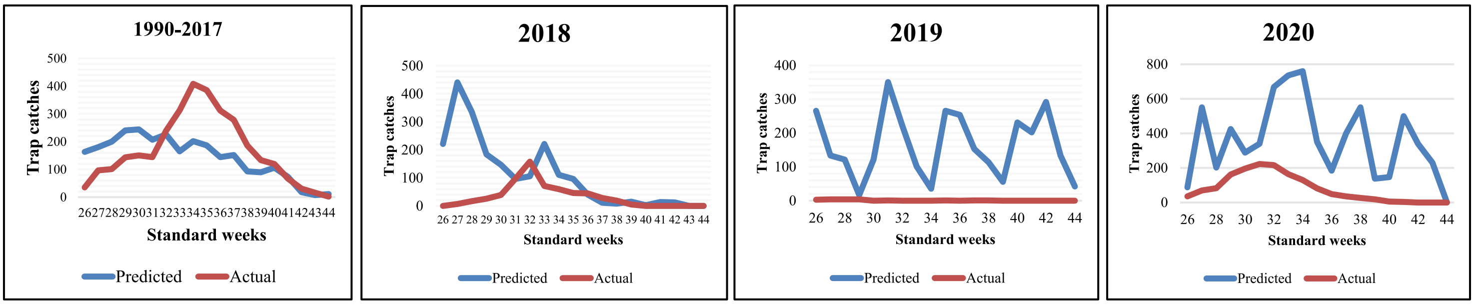

Fig 3. Predicted and actual trap catch from 2017 to 2020

CONCLUSIONS

Spodoptera litura is a notorious polyphagous pest and its severe damage in groundnut crop results in to yield loss. Development of an appropriate prediction module is important for the effective management of this pest. However, the pest being polyphagous, feed and breeds on several others crops too in Dharwad agro-ecosystem. The changing climate and also very slowly declining RH (especially morning RH) may also influence the *Spodoptera* buildup. Changing weather parameter will also affect the microclimate of each crop ecosystem. Further, all the hosts available in an area may not be having similar favorable microclimate and which may or may not suit the *Spodoptera* development. Further, several other factors such as natural enemies including *Metarhizium rileyi* infection during *kharif* will definitely influence the *Spodoptera* population at Dharwad and other similar regions. The present results and statistical analysis clearly indicated that pheromone trap catch based prediction module for *Spodoptera* may go wrong with the existing knowledge about the pest, other biotic, abiotic factors and their interaction. Further, first appearance of moths and their number for consecutive 3 to 5 days may be a simple and practical method to be considered to decide the taking up of protection measures against *S. litura* on groundnut.

ACKNOWLEDGEMENT

The authors are thankful to Directorate of Groundnut Research, Junagadh, and All India Coordinated Research Project on Groundnut, MARS, University of Agricultural Sciences Dharwad

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