Approaches to Weather Based Prediction of Insects: A Case Study on Cotton Pink Bollworm, *Pectinophora gossypiella*

S Vennila, Meenu Agarwal, Dharmendra Singh, Prasenjit Pal and V K Biradar[1]

National Centre for Integrated Pest Management, LBS Building, Pusa Campus, New Delhi - 110 012, India.
[1]Dr Panjabrao Deshmukh Krishi Vidyapeeth, Gadchiroli - 442 605, Maharashtra, India.
E mail: svennila96@gmail.com

Abstract

Pectinophora gossypiella *(Saunders) moth catch-weather relations were established based on eleven years' data (1985 to 1995) recorded at Nagpur of Maharashtra under rainfed cotton growing zone of Indian subcontinent to aid in population predictions. Aggregate and mean models predicting the moth catches were developed through step down regression analyses. Qualitative approach of evolving criteria by comparing moth catches and weather factors of normal and epidemic years together, besides curve fitting of current moth catch abundance alongside of epidemic year were tested. While, quantitative models indicated negative influence of evening relative humidity of previous two weeks on the* P. gossypiella, *the criteria of maximum temperature greater than 34°C during 40th standard week, minimum temperature less than 17°C in 44th standard week, evening and morning relative humidity less than 33 and 70 % in respect of 44 and 46 standard weeks, and dry spell followed by rains coinciding with 41 and 42 standard weeks predicted the severity of* P. gossypiella. *Validations of prediction approaches over four years (2001 to 2004) revealed over as well as under estimations of the quantitative models.*

Key words: *Pectinophora gossypiella*, weather, prediction, validation, cotton

Introduction

Pink bollworm, *P. gossypiella* (Saunders) is a pest of Indian origin with worldwide importance (Wilson and Wilson 1974, Toscano *et al.* 1979, CAB International Institute of Entomology 1990) causing reduction in yield as well as lint quality of cotton. Inability to locate any of its stages readily on the crop poses difficulty in sampling and timely adoption of management measures. As a pest with preference for feeding seeds of maturing bolls, its damage becomes visible only at boll opening stage. Boll and locule infestations up to 72-80 % and 32-40 % respectively have been reported under Indian conditions (Sidhu and Dhawan 1981). In Central India where cotton is grown as rainfed crop, dependent on monsoon, the dates of sowing and harvesting in addition to weather factors play vital role in the carry over and establishment of *P. gossypiella*. Cotton growing season spans between June and February months and population buildup and severe infestation of *P. gossypiella* occurs between August-September and November-December months of every season, respectively (Satpute *et al.* 1983). Larval diapause in soil, plant debris, godowns and ginneries go unnoticed largely during the absence of the host crop and adverse weather conditions, but are the definite sources of infestation in the season that follows. The widespread cultivation of transgenic cotton across the Indian continent has significantly reduced the incidence of pink bollworm (Vennila 2008), however the potential threat exists as the insect occurs when there has been declining levels of Cry protein expression in plants late in the season (Kranthi *et al.* 2005). Hence, it becomes imminent to regularly monitor the pink bollworm presence and abundance even in transgenic cotton ecosystems.

Gossyplure pheromone baited traps have been widely used as a tool for detection and monitoring of *P. gossypiella* since 1980s (Dhawan and Sidhu 1984, Gupta *et al.* 1990, Dhawan and Simwat, 1996) in India. Although regional and seasonal variations of *P. gossypiella* trap catches and boll infestation relationships exist in Egypt (Al-Beltagy *et al.* 1995, Barrania and Al-Beltagy 1996), pheromone catches largely reflected the larval population density and infestation levels at any given time in India (Korat and Lingappa 1996, Dhawan and Sidhu 1988, Karuppuchamy and Balasubramanian 1990, Qureshi *et al.* 1993). Taneja and Jayaswal (1981) established a capture threshold of eight moths/night/trap for insecticidal sprays and has been adopted throughout the country over the last two and a half decades. Currently, recording of seasonal male moth catches using pheromone traps during the crop growing season has been a regular feature of *P. gossypiella* management.

Understanding the factors affecting *P. gossypiella* abundance and describing its population build up in relation to environmental weather variables during the crop season would guide in formulating strategies for its forecasting and management. Elsewhere, the influence of temperature in determining emergence and development of insect population has been established (Higley *et al.* 1986, Wilson and Barnett 1983) and thermal/heat summations or degree-days are used for predicting *P. gossypiella* emergence (Gergis *et al.* 1990, Chu and Henneberry 1992, Beasley and Adams 1996). Available studies on the effect of weather on population build up of *P. gossypiella* in India are either restricted to specify the optimum range of environmental conditions favouring pest development (Chaudhari *et al.* 1999) or the type of pest weather relations without validations (Korat and Lingappa 1995, Rajaram *et al.* 1999). Bishnoi *et al.* (1996) reported optimum temperature and humidity ranges of 22-23 ºC and 52-72 %, respectively for build up of *P. gossypiella*. The only study on forewarning of *P. gossypiella* based on weather parameters through correlation and regression analyses pioneered by meteorologists in association with entomologists, (Ravindra *et al.* 2000) remains untested so far. Hence, the present study was taken up to make use of different quantitative and qualitative approaches based on the available historical data to forewarn the severity of *P. gossypiella* infestation that would be meaningful and simple, and can be replicated to other insect pests.

Materials and methods

Data sets of seasonal male moth catches in gossyplure pheromone baited traps along with weather variables namely, maximum and minimum temperatures (Max T and Min T in ºC), morning and evening relative humidities (MRH and ERH in %) and rainfall (RF in mm) for cotton growing periods between 32 and 52 standard weeks (SW) corresponding to August and December months of eleven years (1985 to 1995), were collated from the Central Institute for Cotton Research at the Nagpur location of Maharashtra State at Central India for the development of prediction models. The seasonal dynamics of *P. gossypiella* was measured through pheromone traps deployed over a cotton farm area of 100 ha at the rate of 5 ha^{-1}, and daily weather data were recorded from observatory located within the same farm. Unit of measurement of *P. gossypiella* trap catches was standard week wise mean values of moth catch/trap/night. The data sets recorded on moth catches and weather variables for four cotton production seasons from 2001 to 2004 at the same locality were utilized for testing the applicability of prediction models.

Polynomial equations of first degree using step wise regression were fitted to develop quantitative prediction models using Microsta® package by utilizing 11 year data sets of standard weekwise moth catches and weather factors. An aggregate prediction model was arrived at considering the standard week wise *P. gossypiella* male moth catches as dependent variable and the five weather variables pertaining to current, one and two lag weeks as independent variables of all years. Secondly, a mean model was developed based on average of moth catches and weather variables in respect of each standard week over years, as dependent and independent variables, respectively.

Thirdly, qualitative approach of comparison between normal and epidemic year variations for each of weather factors and moth catches was made to evolve criteria predicting the severity of pink bollworm build up. Normal of weather factors and moth catches was worked out by averaging the respective variables standard week wise over eleven years. Finally, predicting *P. gossypiella* severity through curve fitting of epidemic and current year's moth catches and of weather factors was made for use in conjunction with the developed criteria by the third approach.

Both the quantitative and qualitative approaches were validated using the data sets corresponding to future values of 2001-2004 from the study location. Moth catch predictions through aggregate and mean models, and observed catches were subjected to two sample't' test for differences between predicted and observed values. The evolved criteria relating to each of the weather factors were tested for each of the four years individually and the severity of *P. gossypiella* was predicted in respect of the agreement or deviation from the established criteria. Observed severity for the validation years was attributed considering the mean seasonal abundance of moth catch being greater or less than the capture threshold of eight moths/trap/night established for Indian conditions. Curve fittings of the dynamics of moth catches of validation and epidemic years along standard weeks were made to test the trends in relation to the latter to forewarn the severity.

Results and discussion

Data base

The mean male moth catches for the years during the growing seasons used in analyses (1985–1995) and validation (2001-2004) are given in Fig 1. The results of the prediction models and their validations are furnished below.

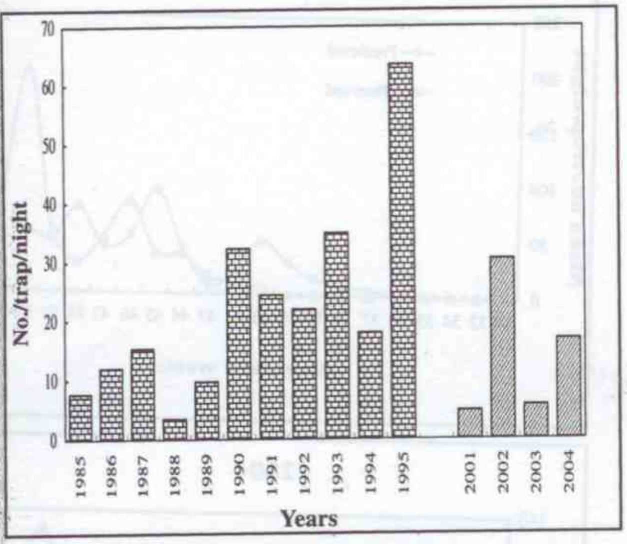

Figure 1. ***P. gossypiella*** **mean moth catches of analytical (1985-1995) and validation (2001-2004) years**

Quantitative models predicting male moth catches of *P. gossypiella*

The estimated equation for the aggregate model worked out to be Y = 4.20 - 0.011 ERH_{-1} - 0.025 MRH_{-1} - 0.023 $MinT_{-2}$ - 0.006 ERH_{-2} with R^2 of 0.63. MRH and MinT lagged by one and two weeks, respectively in addition to ERH in respect of one and two lagged weeks showed significant negative influence. The validation of aggregate model over four years showed better fit during 2002 and 2003 years compared to significant deviations during 2001 and 2004 (Fig 2).

The regression fitted with *P. gossypiella* moth catch and weather variables having data sets averaged over years for each of the standard weeks yielded the model Y = 3.14 - 0.0296 ERH_{-1} - 0.0112 ERH_{-2} with R^2 of 0.97. The mean model revealed the negative influence of only the evening relative humidity of both the lagged weeks. The model

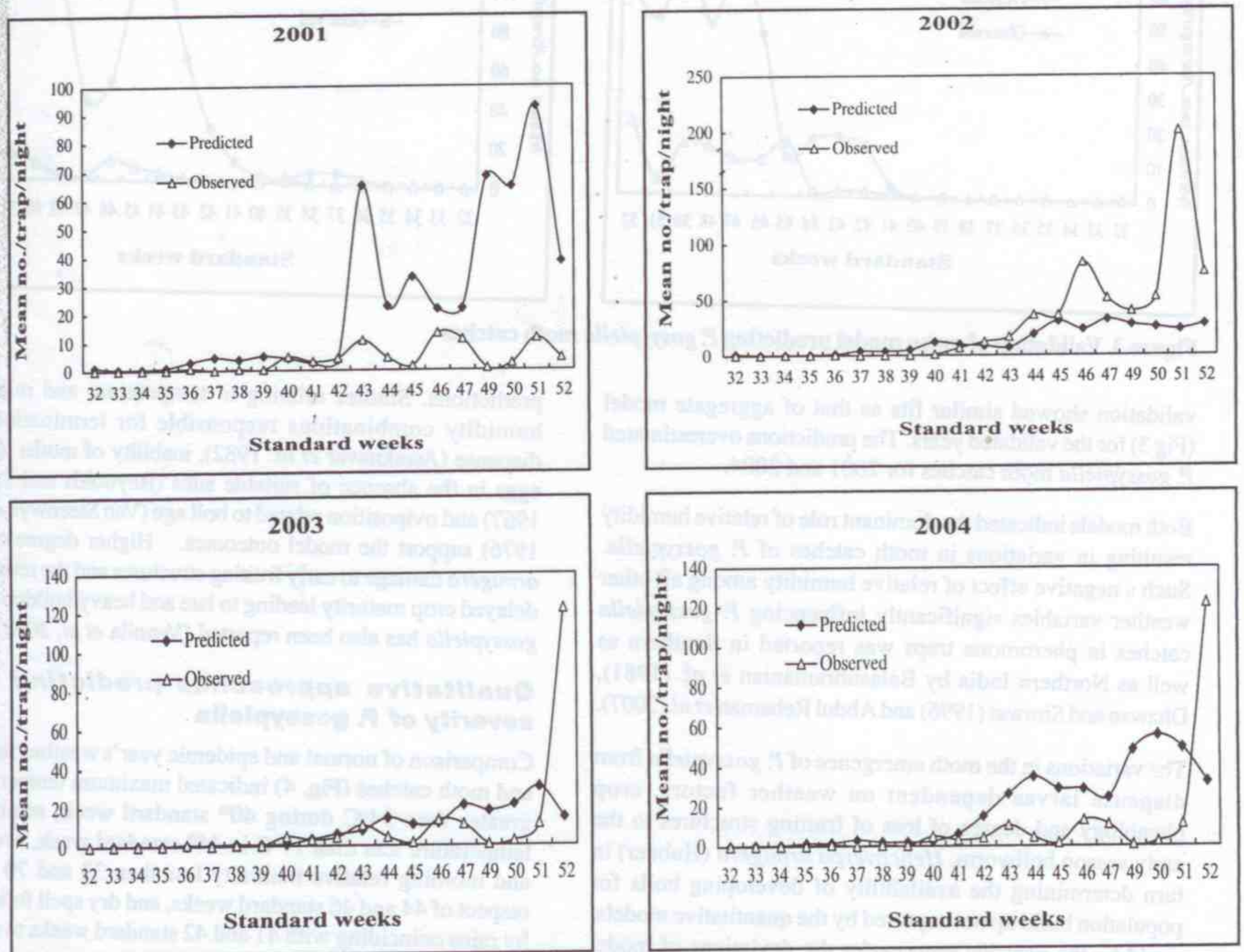

Figure 2. Validation of aggregate model predicting ***P. gossypiella*** **moth catches**

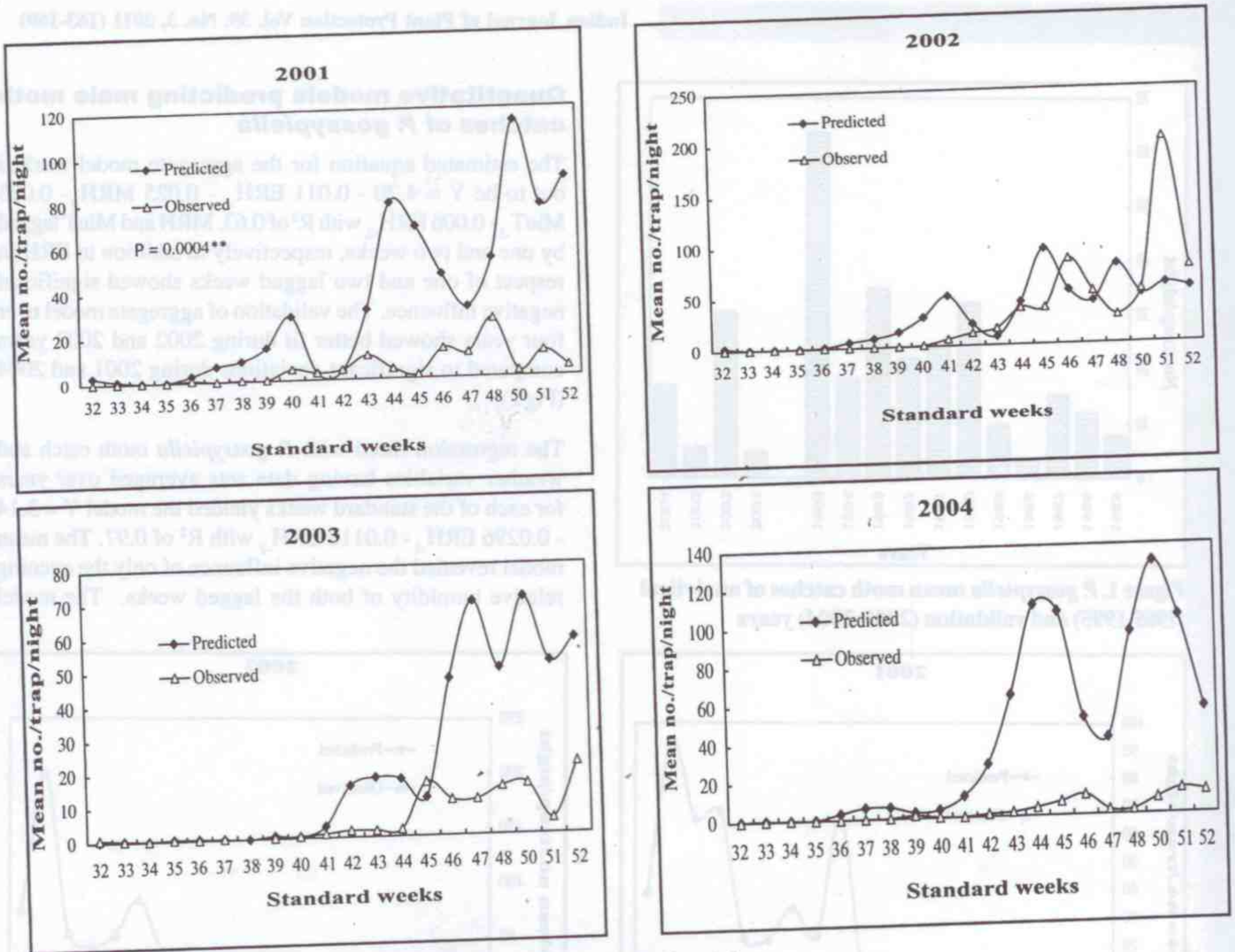

Figure 3. Validation of mean model predicting *P. gosyypiella* moth catches

validation showed similar fits as that of aggregate model (Fig 3) for the validated years. The predictions overestimated *P. gossypiella* moth catches for 2001 and 2004.

Both models indicated the dominant role of relative humidity resulting in variations in moth catches of *P. gossypiella*. Such a negative effect of relative humidity among all other weather variables significantly influencing *P. gossypiella* catches in pheromone traps was reported in Southern as well as Northern India by Balasubramanian *et al.* (1981), Dhawan and Simwat (1996) and Abdul Rehaman *et al.*(2007).

The variations in the moth emergence of *P. gossypiella* from diapause larvae dependent on weather factors, crop phenology and degree of loss of fruiting structures to the early season bollworm, *Helicoverpa armigera* (Hubner) in turn determining the availability of developing bolls for population build up not captured by the quantitative models, could be the possible reasons for the deviations of model predictions. Studies relating to temperature and relative humidity combinations responsible for termination of diapause (Awaknavar *et al.* 1982), inability of moths to lay eggs in the absence of suitable sites (Reynolds and Leigh 1967) and oviposition related to boll age (Van Steenwyk *et al.* 1976) support the model outcomes. Higher degree of *H. armigera* damage to early fruiting structures and the resultant delayed crop maturity leading to late and heavy buildup of *P. gossypiella* has also been reported (Vennila *et al.* 2003).

Qualitative approaches predicting the severity of P. gossypiella

Comparison of normal and epidemic year's weather factors and moth catches (Fig. 4) indicated maximum temperature greater than 34°C during 40[th] standard week, minimum temperature less than 17°C in 44[th] standard week, evening and morning relative humidity less than 33 and 70 % in respect of 44 and 46 standard weeks, and dry spell followed by rains coinciding with 41 and 42 standard weeks to result

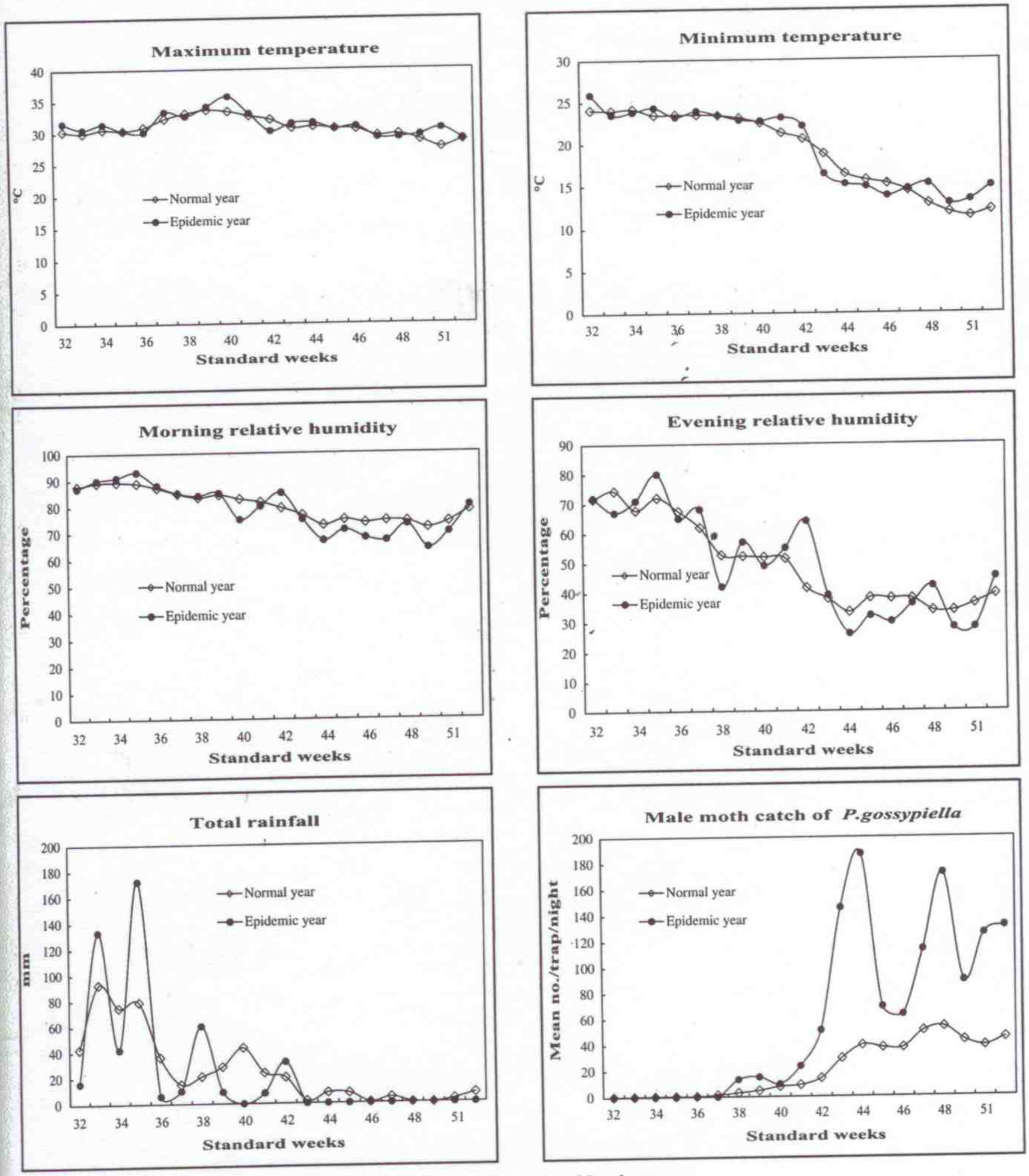

Figure 4. Weather factors and moth catch (MC) of normal versus epidemic years

in higher population of *P. gossypiella* during the season. The predicted severity using the developed criteria based on the observed values of weather factors was made for the four years and is furnished in Table 1. The observed *P. gossypiella* severity was low during 2001 and 2003, and high during 2002 and 2004 (refer Fig 1). A closer examination of the epidemic year (Fig 4) indicated higher build up of *P. gossypiella* at decreased evening relative humidity levels.

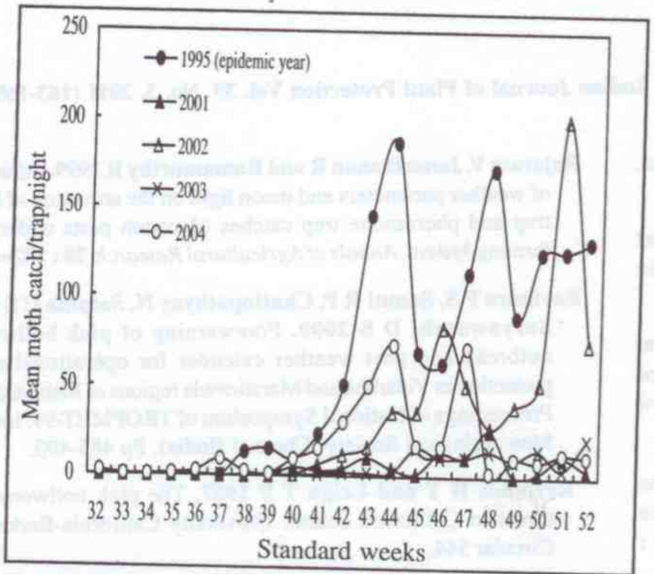

Figure 5. Validation of concurrent preditction of *P. gossypiella* through curve fitting

Concurrent prediction of *P. gossypiella* through composite representation of mean seasonal abundance of moths during the epidemic and current year (Fig. 5) served to forewarn the trend of build up of the pest. The validated severity of *P. gossypiella* based on weather based criteria (Table 1) provided positive validations for all the five weather factors and four years with an exception in respect of rainfall during 2004. The negative relations of minimum temperature, morning and evening relative humidity brought out by the aggregate model as well as the evening relative humidity alone by the mean model of the present study validated the evolved criteria successfully.

Acknowledgements

We thank the financial assistance by World Bank sponsored National Agricultural Innovation Project (NAIP), Indian Council of Agricultural Research (ICAR), New Delhi. Our thanks are also to J. Gadpayle, P. Panchbhai and S. Deole for their assistance in field observations and analyses.

References

Abdhul Rehaman, Nadaf M and Basavana K 2007. Correlation between pink bollworm infestation and weather parameters in Bt and Non-Bt Cotton. *Karnataka Journal of Agricultural Sciences* **20 :** 752-756.

Al-Beltagy A M M, Hamed A M and Moawad G M 1995. Different models of pink bollworm *Pectinophora gossypiella* (Saunders) trap catches and boll infestation relationships under different conditions. *Egyptian Journal of Agricultural Research* **73 :** 1019-1034.

Awaknavar J S, Thontadarya T S and Patil B V 1982. Termination of diapause of the long-cycle larvae of the pink bollworm, *Pectinophora gossypiella* (Saunders), and factors affecting it. *Mysore Journal of Agricultural Science* **16 :** 414-417.

Balasubramanian G, Balasubramanian M and Kulandaivelu R 1981. Prediction of bollworms' damage to cotton in relation to weather factors. *Madras Agricultural Journal* **68 :** 657-659.

Barrania H A and Al-Beltagy A M 1996. Regional and seasonal variations of pink bollworm trap catches and boll infestation relationships. *Journal of Agricultural Research (Alexandria)* **41 :** 77-84.

Bishnoi O P, Mohan Singh, Rao V U M, Ram Niwas, Sharma P D, Singh M and Niwas R 1996. Population dynamics of cotton pests in relation to weather parameters. *Indian Journal of Entomology* **58 :** 103-10.

Beasley C A and Adams C J 1996. Field-based, degree-day model for pink bollworm (Lepidoptera: Gelechiidae) development. *Journal of Economic Entomology* **89 :** 881-890.

CAB International Institute of Entomology 1990. *Pectinophora gossypiella* (Saunders). International Institute of Entomology

Table 1. Validation of weather based criteria predicting the severity of *P. gossypiella*

Weather variables & Standard week(s)	Prediction criteria resulting in severity	Observed values 2001	2002	2003	2004	Predicted severity[a] 2001	2002	2003	2004
MaxT (ºC)40	>34	30.7	36.3	32.3	34.7	Low	High	Low	High
MinT (ºC)44	<17	17.9	16.1	21.8	15.6	Low	High	Low	High
MRH (%) 46	<70	75	70	76.4	59.3	Low	High	Low	High
ERH (%)44	<31	33	28	51.7	27.9	Low	High	Low	High
RF (mm)									
41	Dry spell followed	3	0	6	0	Low	High	Low	Low
42	by rains	0	21	0	0				

[a] Observed severity of *P. gossypiella* was low and high during 2001& 2003, and 2002 & 2004, respectively based on the mean seasonal abundance in relation to the capture threshold of eight moths/trap/night

Distribution Maps of Pests Series A (Agricultural), Map No. 13, 3rd rev.

Chaudhari G B, Bharpoda T M, Patel J J, Patel K I and Patel J R 1999. Effect of weather on activity of cotton bollworms in middle Gujarat. *Journal of Agrometeorology* **1 :** 137-142.

Chu C C and Henneberry T J 1992. Pink bollworm (Lepidoptera: Gelechiidae) male moth trap catches in gossyplure-baited traps in relation to accumulated heat units. *The Southwestern Entomologist* 17 : 79–87.

Dhawan A K, and Sidhu A S 1988. Correlations between the moth catch in gossyplure baited trap and pink bollworm incidence in F 414 *hirsutum* cotton. *Indian Journal of Entomology* **50 :** 55–60.

Dhawan A K and Simwat G S 1996. Monitoring the seasonal abundance of cotton bollworms with pheromone traps. *Indian Journal of Ecology* **23 :** 123-129.

Gergis M F, Moftah E A, Soliman M A and Khidr A A 1990. Temperature-dependent development and functional responses of pink bollworm, *Pectinophora gossypiella*. *Assiut Journal of Agricultural Science* **21 :** 119-128.

Gupta G P, Kishore P and Vashisht A K 1990. Monitoring of pink bollworm, *Pectinophora gossypiella* (Saunders), males through pheromone traps and weather parameters affecting population buildup. *Journal of Entomological Research* (New Delhi) **14 :** 21-29.

Higley L G, Pedigo L P and Ostlie K R 1986. DEGDAY - A program for calculating degree-days and assumptions behind degree-day approach. *Environmental Entomology* **15 :** 999-1016.

Karuppuchamy P and Balasubramanian M 1990. Field evaluation of gossyplure the synthetic sex pheromone of *Pectinophora gossypiella* in Tamil Nadu India. *Indian Journal of Entomology* **52 :** 170-9.

Korat D M and Lingappa S 1995. Influence of weather factors on the pheromone trap catches of cotton bollworm moths. *Indian Journal of Plant Protection* **23 :** 188190.

Korat D M and Lingappa S 1996. Monitoring of pink bollworm moths with sex pheromone traps and its relationship with larval population and field incidence. *Karnataka Journal of Agricultural Science* **9 :** 432-437.

Kranthi K R, Naidu S, Dhawad C S, Tatwawadi A, Mate K, Patil E, Bharose A A, Behere G T, Wadaskar R M and Kranthi S 2005. Temporal and intra-plant variability of Cry IAc expression in *Bt* -cotton and its influence on the survival of the cotton bollworm, *Helicoverpa armigera* (Hubner) (Noctuidae: Lepidoptera). *Current Science* **89 :** 291-298.

Qureshi Z A, Ahmad N and Hussain T 1993. Pheromone trap catches as a means of predicting damage by pink bollworm larvae in cotton. *Crop Protection* **12 :** 597–600.

Rajaram V, Janarthanan R and Ramamurthy R 1999. Influence of weather parameters and moon light on the attraction of light trap and pheromone trap catches of cotton pests under dry farming system. *Annals of Agricultural Research* **20 :** 282=285.

Ravindra P S, Samui R P, Chattopathyay N, Satpute U S and Suryawanshi D S 2000. Forewarning of pink bollworm outbreak and pest weather calender for operational crop protection in Vidarbha and Marathwada regions of Maharashtra. Proceedings of National Symposium of TROPMET-99, Indian Meteorological Society; Chennai (India). Pp 485-490.

Reynolds H T and Leigh T F 1967. The pink bollworm: A threat to California cotton. University California-Berkeley, Circular 544.

Satpute U S, Bhalerao P D and Taley Y M 1983. The population level of adult male moths of pink bollworm in cotton season. *Cotton Development* **13 :** 39.

Saunders W W 1843. Description of a species of moth destructive to the cotton crops in India. *Transactions of the Royal Entomological Society of London* **3 :** 284285.

Sidhu A S and Dhawan A K 1981. Testing of azinophos-methyl for the control of the pink bollworm. *Pesticides* **15 :** 7-9.

Taneja S L and Jayaswal A P 1981. Capture threshold of pink bollworm (*Pectinophora gossypiella*) moths on *hirsutum* cotton. *Tropical Pest Management* **27 :** 318-324.

Toscano N C, Van Steenwyk R A, Sevacherian V and Reynolds H T 1979. Predicting population cycles of the pink bollworm by thermal summation. *Journal of Economic Entomology* **72 :** 144-147.

Van Steenwyk R A, Ballmer G R and Reynolds H T 1976. Relationship of cotton boll age, size and moisture content to pink bollworm attack. *Journal of Economic Entomology* **69 :** 579-582.

Vennila S 2008. Pest management for cotton ecosystems or ecosystem management for cotton production? *Current science* **94(11) :** 1351-1352.

Vennila S, Panchbhai P R, Ramteke M S and Biradar V K 2003. Crop phenology, pink bollworm (*Pectinophora gossypiella*, Saunders) damage and yield of cotton hybrids in relation to sowing dates. *Journal of Cotton Research and Development* **17 :** 65-70.

Wilson L T and Barnett W W 1983. Degree days: an aid in crop pest management. *California Agriculture* **37 :** 4-6.

Wilson R L and Wilson T D 1974. Laboratory diets for screening cotton for resistance to pink bollworm. *Cotton Growing Review* **51 :** 302-308.

Received : 04-05-2011 Accepted : 10-09-2011