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e-pest surveillance system for soybean (*Glycine max*) and cotton (*Gossypium* spp) crops

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ABSTRACT

A web-based decision support system called e-pest surveillance system was developed and implemented for effective and regular pest monitoring in soybean [*Glycine max* (L.) Merrill] and cotton (*Gossypium* spp) crops in Maharashtra. Epidemics of *Spodopetra litura* (Fab.) occurred during 2008–09 in an area of 1.46 million ha caused loss of 0.85 million tonnes and monetary loss of INR 1.39 billion, which led to the immediate need for systematic area wide pest monitoring. Application of web technologies speeded up the whole process of pest surveillance and appropriate actions to be taken to manage pests by the farmers. The System consists of three major components, viz. a database, an offline data capture and online data reporting and advisory applications. Information of the incidence of key pests of selected crops collected through regular monitoring by State Department of Plant Protection personnel at farmer's field was fed into the offline data capture application deployed at their computers and subsequently transferred to central database. Pest management experts from State Agriculture Universities (SAUs) accessed the pest reports generated on the central database through online reporting and advisory application. Decisions of pest management were made on the basis of these reports by state pest experts and issued as advisories to farmers through short message service (SMS) for implementation. This describes the structure and functions of the e-pest surveillance system, which seeks to be first of its kind in Indian agriculture for pest management at farmer's field level.

Key words: Database, Google map, Pest advisory, Pest monitoring, Pest reports, *S. litura*, Semilooper, SMS

Cotton (*Gossypium* spp) and soybean [*Glycine max* (L.) Merrill] crops are grown in an area of 3.104 and 3.1 million ha, respectively in Maharashtra. These crops are infested by several insect pests and diseases. The lepidopteron insects, viz. *Helicoverpa armigera* (Hub.) and *Spodoptera litura* (Fab.) are the major pests of both the crops across the state. The infestation of *S. litura* coupled with *H. armigera* and other leaf eating caterpillars on soybean in Maharashtra during 2008–09 in an area of 1.46 million ha caused yield loss of 0.85 million tonnes and monetary loss of INR 1.39 billion. In Vidharba region it caused severe yield losses covering an area of 0.75 million ha (Dhaliwal and Koul 2010), which led to the need of systematic area wide pest monitoring. Since regular and wide area pest monitoring is the cornerstone for pest management (Grant *et al.* 2006), through which epidemic situations can be avoided by detecting damage prior to establish at a higher pest population. Pest monitoring provides field-specific information on pest pressure and crop injury leading to appropriate selection and application of pest management procedures by pest management experts *(ISPM No. 6: Guidelines for surveillance, 1997. FAO)*. So to automate the process of pest monitoring a web based system was developed by integrating the potential technical and administrative stakeholders of State and Central machinery involved in plant protection. Use of web technology helped in providing prompt and reliable pest reports to the concerned agencies and thus confirmed the operation of effective monitoring.

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MATERIALS AND METHODS

Regular and effective pest monitoring requires proper planning and execution for data collection in the farmer's

field. Since It was very difficult to observe all fields and plants, hence appropriate plan and procedures for field selection, pest sampling and method of monitoring were developed to get the accuracy of data considering time and labour requirements (Fishel *et al.* 2009), representing the whole area under soybean and cotton in the state. Two types of pest monitoring were carried out, viz. pest surveillance and roving survey. Under pest surveillance, quantitative observations on key pests were recorded from fixed and random fields of selected villages as per the sampling plan on fixed time schedule using the customised data recording formats for each crop. In roving survey, qualitative pest status was recorded from randomly selected fields of villages other than villages selected for pest surveillance except for *S. litura*. Selected fields were regularly monitored starting from crop emergence to harvest. 84 pest surveillance units were established across the state for the implementation and execution of the activity. Area of surveillance under each unit was clearly demarcated and required man power such as pest monitors, computer personnel and IT tools, viz. laptop, internet connection and GPS devices were provided.

30 000 villages from 271 blocks in 28 districts across the state were selected for pest surveillance during 2009–10 and 2010–11. The villages were clustered into 8 000 ha area of soybean and cotton. The villages having maximum area under soybean and cotton crops were selected for pest surveillance. For 1 000 ha area under either of the crop or both, two fixed and two random fields were selected for scouting. Fixed and random fields were selected from different directions of the village. The number of fixed and random fields was selected on the proportionate crop area basis. If crops grown in 50: 50 ratio in a village, equal number of fixed and random fields were selected from each crop. If one crop covered 70–90% of the area, all fixed and half of random plots were selected from that crop and half of random plots were taken from another crop. If area exceeding more than 90% for one crop in a village, all the fields were selected from the crop. In case of crop area less than 1 000 ha in the cluster of villages, then the villages having maximum area were taken into account. During this process, it was ensured that the selected village represents the cluster of villages. In each Block, a list of villages was prepared which were not selected for pest surveillance, considered for roving survey. In rowing survey, around 10–15 fields spread over minimum 10 villages were observed in a single day twice in a week.

Separate proforma were designed for each crop with technical inputs from pest management experts for recording observations in the fields. Details about the fields, pests and other relevant information were the core components of data collection format. Each field was given a unique ID for surveillance and its geographical coordinates, viz. latitude and longitude were recorded using GPS devices. All the relevant information about the field such as ownership, variety, sowing date, seed rate, intercropping systems, irrigation, pesticide sprayed and fertilizers applied were recorded. The unit of observation was one acre. The sampling units for pest observations varied with crops, insects and diseases.

A weekly schedule was fixed for recording pest observations, data entry and sending advisories to the farmers. Field scout had to take observations on four days in a week, viz. Monday, Tuesday, Thursday and Friday. The recorded data was entered into the "e-pest surveillance" system after verification on Wednesday and Saturday and subsequently transferred into the central database. The roving survey data was also entered into the database by the end of the week. Pest experts from State Agriculture Universities (SAUs) were given access to view the pest reports of the data, submit suitable advisories into the online reporting and advisory application by Thursday and Monday and disseminated to the farmers on same day through SMS.

Keeping in view the size of data and internet connectivity in remote areas of state, three tier architecture based system was designed consisting three major functional components, viz. a database, offline data entry and transfer application and online pest reporting and advisory application. The interconnection and arrangement of these modules is shown in Fig 1.

Information flow chart of the system is mentioned below:

Data collection → offline data entry → data verification, compilation and transfer into database → online pest reporting and advisory issuance → pest advisory dissemination

The system was developed in ASP.net environment using C# & Java languages, Google@ API, SQL Server 2000 and XML technologies. The development of the system was very systematic and accomplished in different phases, having elaborate discussions with all the stakeholders and insertion of their valuable suggestion.

The database is the core component of the system. Once the scope of database finalized, the next step was to define the information needed by users. A blueprint of the database

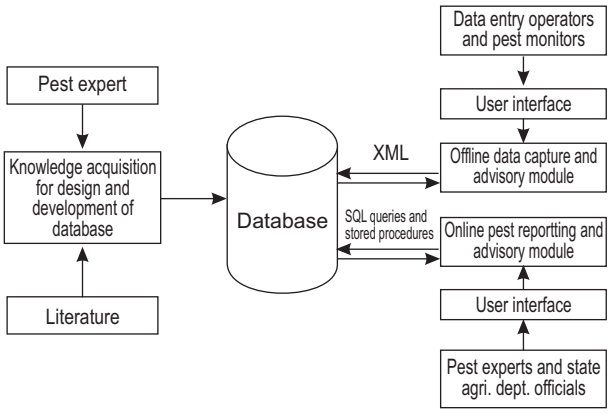

Fig 1 Structure of the system

was developed in consultations with the domain experts, review of published research papers, pest management guides and pesticide databases. With blue print in hand, we moved to the physical design of the database by determination of specific storage, access methods and structures. Database was created using SQL Server 2000. A total of 19 tables consisting 120 data fields were created for storage of information such as user details, location details, field details, pests and other relevant information such as trap catches, fertiliser, pesticide sprays, irrigation etc. Relationships were established among these tables to avoid data redundancy. Various stored procedures were written for data manipulation. Dummy data was entered into the database for testing purpose since it is easier to change the database during testing phase.

A comprehensive coverage was established by creating a solid foundation for the system powering its functionality and integration capabilities, efficiently supporting application workflows and data manipulation. Due emphasis was given on database security and user access management.

This application was designed to facilitate the users to enter, check and compile the data offline. For each surveillance unit, a setup file was created so as to make the application functional for capturing the data of the area under its observation. This application started as standalone by introducing itself and asks the data entry operator for login. After successful login, data entry started on the page (Fig 2) of the application having links viz. village registration, field registration, pest data entry and data uploading. Other information such as trap catches of *S. litura,* fertiliser, irrigation, pesticide spray details could also be entered into the application. This also had the provision for data viewing and editing before transferring into the database. After compilation, data was transferred into database as and when internet connectivity is available. XML was used for exchange of information between various components of the system through internet.

Algorithm for field registration and data entry

Select {year, crop, season}

Select {State, District, Block, Village}

Enter {field geospatial coordinates}

Date of observation then submit. The field registration is over.

If {crop} = "Cotton"

Data entry form for cotton pest data entry is generated. Finally user submits the data.

IF "data correct" = "yes" then compile data into a zip folder in XML files

Else "edit" data and then compile data into a zip folder in XML files

Check internet connectivity If available, transfers the data into the database.

An online application was designed and developed as user interface for pest reporting, mapping and issuing advisories to the farmers. Start-up page of the application

Fig 2 Pest data entry view

was linked to NCIPM (www.ncipm.org.in) home page. It has four modules: admin; pest reporting; pest mapping; pest management advisory. Admin module facilitated database management; user creation; assignment of user access rights; creating setups for various monitoring units.

Pest reporting module generated three kinds of pest reports, i e administrative reports, general pest reports and Economic Threshold Level (ETL) based pest reports (Fig 3). Administrative reports were designed to track the progress of various activities of the programme. The managers were able to track the progress of data entry and advisory by different monitoring units through these reports.

General pest reports provided current and temporal (date wise or standard week wise) pest information of a location, which could be viewed for both quantitative and qualitative information. ETL based reports facilitated the pest experts in advising the state agencies and farmers for appropriate pest management measures if the pest situation warranted so. These reports could be viewed in two formats tabular and graphical district/bock/village wise while ETL based reports could be viewed as division/district/block wise.

The ETL based report generated based on the user selection criteria is as follows:

Select [Crop] = “Soybean” and
[Pest]=” Semilooper “ and
[Division]=”Nagpur” and
[District]=”Nagpur” and
[Block]=”Umred” and
[From date]=” 10/08/2010 “ and [To date]=” 30/08/2010"
Then “Submit”

Division	District	Block	Village	Observation Date	Semilooper (nos per meter)
Nagpur	Nagpur	Umred	Bothali	23/08/10	7.60
Nagpur	Nagpur	Umred	Mohapa	24/08/10	5.80
Nagpur	Nagpur	Umred	Pipra	24/08/10	6.50

Note: Red color cells are the locations having pest population above ETL

Submit [Pest advisory] = spray the crop with NSKE 5% or *Beauveria bassiana*

4 g/litre of water or Chlorpyrifos 20 EC @ 1.5 litres/ha or Quinalphos 25 EC @ 1.5 litres/ha. [Water @ 500 litres/ha]

The highlighted box in Table 1 showed population of semilooper above ETL in Umred block of Nagpur district which required immediate pest management intervention. On the basis of pest situation, experts suggested appropriate management practices to be applied in the field which were immediately available on system website in brief and detailed

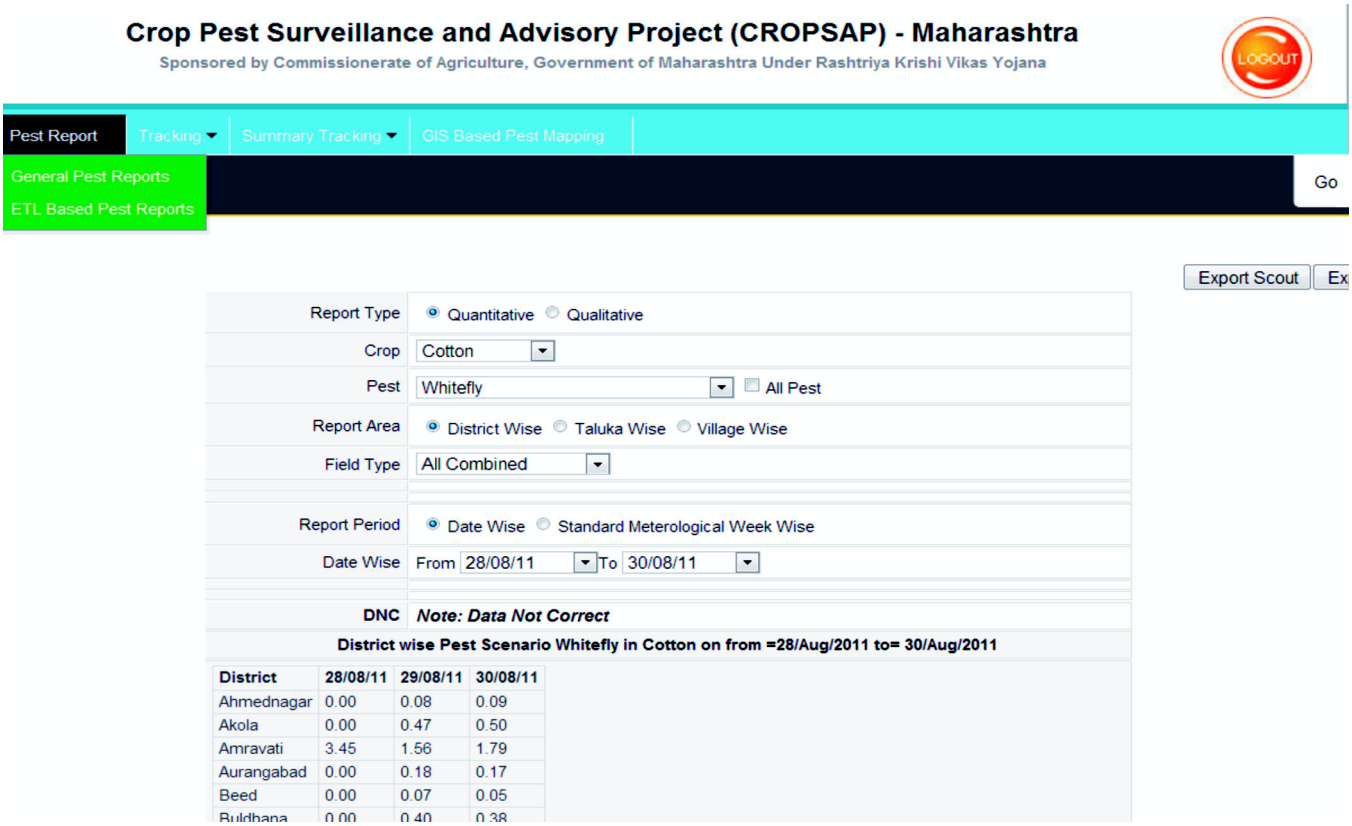

Fig 3 Pest reporting view

formats and a copy of brief advisory was disseminated to the farmers through SMS.

The purpose of pest reporting was to communicate immediately the potential danger arising from the occurrence, outbreak or spread of a pest. Since accurate and timely availability of information on pest status facilitates taking appropriate and quick actions of pest management, and thus helps to minimize pest damage. Critical inputs required for pest management too were timely arranged as per available pest status.

Pest reports were designed such as to clearly indicate date(s) of the pest report, status of the pest, geographical distribution and nature of the immediate or potential danger from pest (*ISPM No. 17: Pest reporting, 2002. FAO)*

Reporting module also generated various other reports such as trap catches, ETL based area estimates reports showed how much area was having above ETL population of a pest during specified period.

Third module of the application, i e pest mapping module showed the pest status on Google maps. The geographical coordinates of locations recorded using GPS devices in the surveillance execution provided the basis for thematic tempo-spatial pest maps. This application works on data managing layers. The first one is core layer of polygons vectors maps for country, state, districts and block. It is also capable to depict village polygons for the selected block under the desired district. The Google Map API was used to display the polygons as administrative boundaries on different scales. The Google® Maps API is relatively easy to programme using many programming languages (Xia *et al*. 2009). The authentic vector polygons maps from Survey of India were used for state, district, block and village using GIS Arc info software. The application opens with multi selection options such as division, district, block, monitoring type, crop, and name of pest, pest intensity of pests, dates or standard week. Based on user selection, module extracts the relevant information from database through SQL query and populates the results on Google map. The leftmost part of the map view shows the legends of the map viz. pest intensity with colour codes, pest name and the selected dates/standard week. Map of incidence of *S. litura* solitary larvae on Soybean crop in all blocks of district Jalgaon for the 35th standard week is shown in Fig 4. In this map, blocks of Jalgaon district are highlighting the affected locations.

RESULTS AND DISCUSSION

During 2009–10 and 2010–11, total 224 550 and 252 613 quantitative; 17 588 and 25 714 qualitative pest observations were recorded and entered into the system in both the crops viz. Cotton and Soybean respectively. A total of 3 504 and 5 960 advisories for pest management were issued by pest experts and disseminated through 13 93000 and 74 87351 SMSs (Table 1) during these years respectively to all registered farmers in 28 districts of seven divisions of the state. Real time pest advisories in notified villages were issued twice in a week using ETL based reporting module of

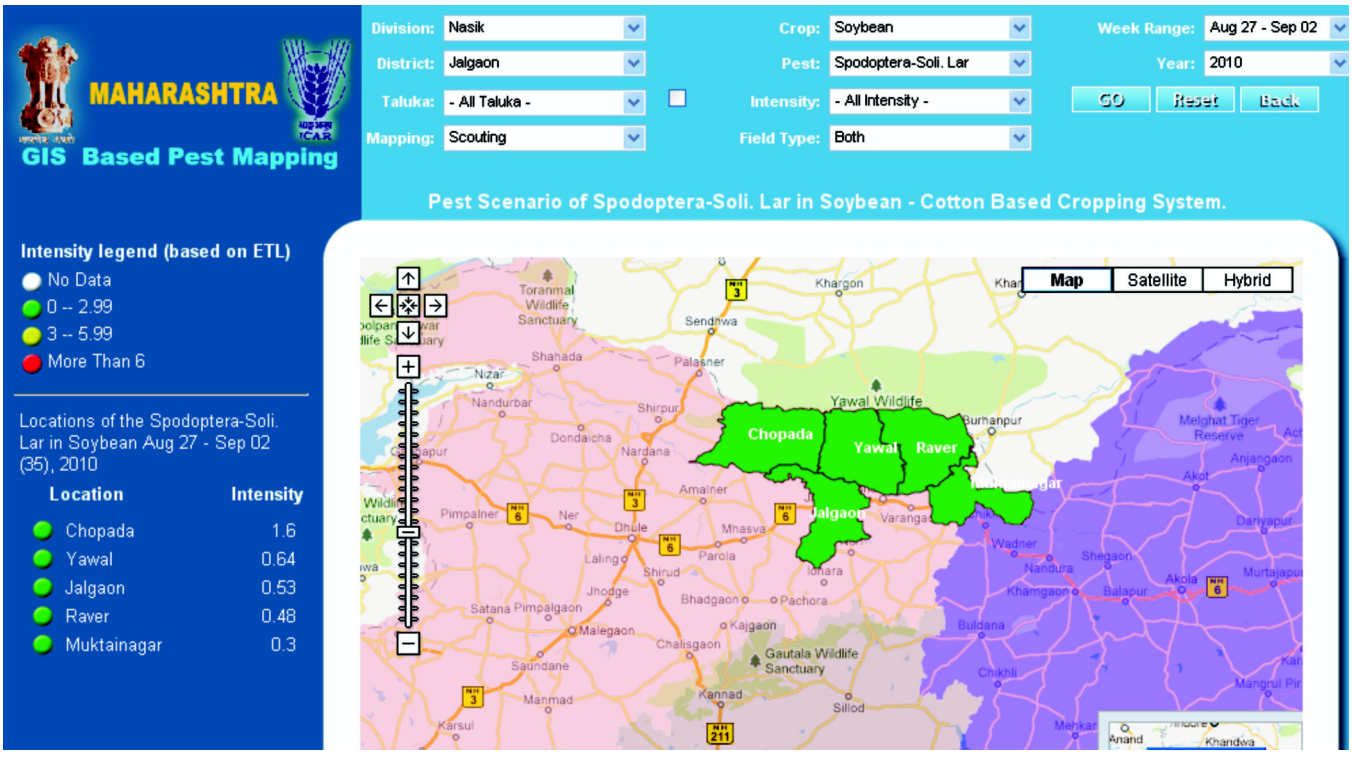

Fig 4 Pest mapping view

Table 1 Data entries and pest management advisories for soybean and cotton (2010–11)

Division	Data entries (nos)				Pest advisories issued by SAUs (nos)		SMSs sent to farmers for advisories (nos)	
	Pest scouts		Pest monitors					
	2009-10	2010–11	2009–10	2010–11	2009–10	2010–11	2009–10	2010–11
Amravati	78 142	89 416	5 449	7 464	935	1 256	326 148	1 498 254
Aurangabad	33 579	3 611	2 247	3 688	419	630	176 220	994 491
Kolhapur	3 985	4 036	324	795	190	522	152 184	952 199
Latur	40 664	50 465	3 751	5 926	733	1 088	156 408	986 474
Nagpur	32 667	33 951	2 956	3 684	507	931	316 300	1 413 106
Nasik	30 609	33 702	2 068	2 769	551	912	141 510	833 567
Pune	4 904	4 632	793	1 388	169	621	121 230	809 260
Total	224 550	252 613	17 588	25 714	3 504	5 960	13 93 000	74 87 351

the system.

Pest status of cotton

As reported by the system during 2009–10, incidence of leaf reddening was common almost across all the districts of the state. Wardha district had the highest incidence of leaf reddening followed by Amravati, Chandrapur, Beed and Yeotmal. Akola and Jalna districts were the hot spot for the occurrence of jassids. In 2010–11, the incidence of jassids and leaf reddening appeared across all the districts. Wardha and Jalgoan districts had higher incidence of jassids than other districts, whereas the incidence of leaf reddening was

Table 2 Summary of ETL pest status of cotton 2010–11 (no. of occasions above ETL)

Division	District	Spodoptera litura (no./m)			Whitefly (no./3 leaves)	Thrips (no./3 leaves)	Jassids (% incidence)	Red leaves (% incidence)	*S. litura* (male moths/ trap/night)
		Egg mass	Greg. lar	Soli. lar					
Amravati	Akola	1					679	692	
	Amravati	1		12	1		328	679	2
	Buldhana			1			841	861	1
	Washim				1		6	239	
	Yeotmal	1					459	1 402	20
Aurangabad	Aurangabad		1				903	795	
	Beed		1				97	1 133	74
	Jalna						405	864	
Latur	Hingoli						416	350	
	Latur							5	
	Nanded	1		6			739	1 242	12
	Osmanabad							10	
	Parbhani						404	827	7
Nagpur	Bhandara								
	Chandrapur						11	659	15
	Gadchiroli						9	7	
	Nagpur		1				248	611	25
	Wardha						1 856	1 358	3
Nasik	Dhule							19	
	Jalgaon						1 856	696	
	Nandurbar							133	
	Nasik						106	94	4
Pune	Ahmednagar						347	611	
	Solapur							2	

Table 3 Summary of ETL pest status of soybean 2010–11 (no. of occasions above ETL)

Divisions	Districts	*Spodoptera litura* (no./m)		Semi Looper (no./m)	*H. armigera* larvae (no./m)	Girdle beetle damage (no./m)	*S. litura* (% incidence)	*H. armigera* trap catches (moths/t./nt.)
		Egg mass	Soli. lar					
Pune	Ahmednagar		13	1				
	Solapur							
Amravati	Buldhana			170		2	41	
	Akola			216				
	Amravati			515	1		4	
	Washim			68		1	16	
	Yeotmal	1	1	303		2	27	1
Aurangabad	Beed						107	
	Aurangabad							
	Jalna			1				
Latur	Parbhani						8	
	Nanded	4	2	4		3	43	3
	Latur						19	
Nagpur	Nagpur			40		10	80	
	Chandrapur						25	
	Gadchiroli		3				40	
	Bhandara					5	14	
	Wardha	1		42	1	245		
Nashik	Nandurbar					1		
	Nashik							
	Dhule					18		

recorded highest in Wardha and Yeotmal (Table 2). Nanded and Beed districts were also recorded with appreciably high incidence of leaf reddening. Suitable pest advisories were issued to all the registered farmers of these districts and pest management was achieved in time. As report generated for 2010–11, overall sucking pest situation in cotton was below ETL across the state but occasional incidence of *S. litura* above ETL was recorded on few dates in Amravati, Nagpur and Aurangabad districts.

Pest status of soybean

As per pest reporting system, soybean crop was mostly affected by semilooper in July-August, 2009–10, followed by *S. litura*. In Gadchiroli, Chandrapur, Nagpur districts, *S. litura* and semilooper incidence was above ETL (> 5 nos/ m row) and farmers adopted pest management measures as advised by pest experts through SMS. The infestation of these pests reduced drastically to below ETL from September end. All the districts of Nagpur and Amravati divisions were the hotspot for semilooper during this year. Summary pest incidence above ETL during 2010–11 on soybean crop is presented in Table 3, which indicated that semilooper incidence was appreciably higher in five districts of Amravati division than the districts of other divisions whereas *S. litura* incidence was quiet high in most of the districts. The incidence of semilooper on soybean above ETL level was observed in districts of Amravati, Latur and Nagpur divisions from mid July to mid August. Infestation of girdle beetle was sporadic in Buldhana, Bhandara, Nagpur, Dhule and Nandurbar districts. Wardha district of Nagpur division recorded highest incidence of girdle beetle. System helped in issuing appropriate pest management measure to the farmers of these districts through SMS.

Development and implementation of e-pest surveillance system was an innovative approach of using web technology for pest management. This system helped in quick identification of hot spots and geared up the field staff to manage the impending crisis in an extensive area under pest monitoring. The awareness campaigns integrated into the programme also helped in timely implementation of the programme. The yield of soybean increased on an average 2–3 q/ha as compare to previous year (2008–09), primarily attributed to the minimization of losses caused by pests through effective pest management measures. Dissemination of pest advisories in the form of SMSs helped farmers to adopt appropriate pest management strategies. Besides, the system stored the pest data in standard formats at a central place which could be utilised for drawing inferences in the future times. Such a data base combined with weather data base could be a potential source for development of

forewarning models for insect pests and diseases.

Use of "e-pest surveillance system" as a tool in pest management, benefited the farmers in terms of lesser pest incidence *vis-à-vis* conservation of beneficial insects by timely action with appropriate plant protection measures and popularisation of eco-friendly management practices. The programme also benefited in terms of employment generation, knowledge sharing among technocrats and efficient extension of pest management technologies. This technology seems to be applied 1st time for the pest management in India and we got encouraging response from the all stakeholders.

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