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Design and implementation of web-based aphid (*Lipaphis erysimi*) forecast system for oilseed *Brassicas*

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ABSTRACT

Oilseed *Brassicas* are major crops in India and world over. Keeping in view severe losses caused by aphid (*Lipaphis erysimi*) in these crops, efforts were initiated to devise user-friendly web-based software for forecasting their occurrence. Multiple stepwise regressions have been followed for developing aphid prediction models in practice. Interpretation and use of these models was difficult for any person not having proper statistical knowledge. Further, keeping in view the need of online software tool to help the plant researchers, extension personnel and farmers in forecasting of aphid infestation and timely application of control measures, the study was carried out. This paper introduces design and implementation of web-based forecast software for prediction of aphid on oilseed *Brassicas* in India. The software uses statistical prediction models developed based on weather parameters as independent variables and crop age at time of first appearance of aphid on crop, peak number of aphid and crop age at peak population as dependent variables, which were fitted by multiple stepwise regressions. The software has been developed by deploying ubiquitous unbeatable open sources technology. The system provides a prediction of mustard aphid infestation well in advance of their actual arrival on the crop along with recommendations for need-based insecticide application.

Key words: *Brassica*, Forecast software, *Lipaphis erysimi*, Prediction model, Web-based system

Globally India ranks third in production of oilseeds *Brassicas* and contributes 14.8% of world production. In India, oilseeds *Brassicas* contribute 23.7% of acreage, 26.0% of production of and play an important role in oilseeds economy (Chauhan and Jha 2011). Of the various insect-pests and disease-limiting rapeseed-mustard productivity, *Lipaphis erysimi* (Kalt) continues to be an enigmatic problem in husbandry of oilseeds *Brassicas* in India. It is favoured by low temperatures (8–18°C) coupled with 60–80% relative humidity and cloudy weather. Losses due to mustard aphid can reach up to 80% when conditions favour multiplication of the insect-pest (Mandal *et al*. 1994) and are very difficult to manage when conditions are favourable. Yield losses due to aphid infestation on oilseeds *Brassicas* could be regulated by stage of attack, timing or severity of infestation and thermal requirement for crop, aphid development, which could differ between seasons and regions (Roy *et al*. 2005, Bhattacharya *et al.* 2007). It continues to be the most destructive insect-pest of rapeseed-mustard despite decades of research towards its management. Weather has a very important role to play in the appearance, multiplication and spread of the insect-pest. Considerable efforts have been directed towards developing aphid resistant cultivars. But due to absence of stable, desirable and diverse source of resistance to the mustard aphid with a broad genetic base, systematic use of insecticides has been the most practical way to manage *L. erysimi*. However, due to high cost of chemicals as well as their hazardous effects, use of insecticides need to be only need-based. Although consumption of systemic insecticides on rapeseed-mustard crops in India is high (IASRI 2009), timing their application has been erratic. Crops requiring treatment have been left unsprayed and others sprayed unnecessarily. Moreover, farmers are sometimes forced to skip the actual date of insecticide application due to lack of knowledge regarding the actual time of appearance of the insect-pest. Therefore, for the judicious use of insecticides, effective forewarning system of mustard aphid is very important.

Knowledge to describe the relationship between mustard aphid severity and environmental conditions is limited. Efficient and environment-friendly control of the aphid may be obtained through knowledge of its timing of attack in relation to weather factors, which may enable prediction of

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its occurrence so as to allow growers to take timely action in an efficient manner for crop management. Weather is an important factor in the population dynamics of *L. erysimi*. Models have been developed based on weather parameters, viz. temperature, relative humidity and duration of bright sunshine to forecast crop age at time of attack of *L. erysimi*, peak number of aphid and crop age at peak population of the insect-pest (Chattopadhyay *et al.* 2005, Bhattacharya *et al.* 2007). The aphid forecasting models used in the system were also evaluated in previous studies. However, use of these models by extension personnel, researchers and farmers to manage aphid have been limited because the models are expressed as equations and extension personnel, farmers are not acquainted with their interpretation. Keeping in view such indication by Chattopadhyay *et al*. (2005), the objectives of this research was envisaged to develop and implement a web-based forecasting system to predict mustard aphid while helping rapeseed-mustard growers in India avoid unnecessary application of insecticides and reduce production cost.

Design and implementation of web-based user-friendly system using these statistical models for forecasting of mustard aphid and recommendations regarding management options has been presented in this study. Open source ubiquitous unbeatable Linux, Apache, MySQL and PHP (LAMP) technology has been deployed in the development of the web-based mustard aphid forecast system.

MATERIALS AND METHODS

An important aspect of the design methodology used for developing this mustard aphid forecasting system was a strong interaction with researchers, extension personnel and growers at the Directorate of Rapeseed-Mustard Research (Kumar *et al.* 2008, 2010; Pavan *et al.* 2011).

The historical data of weather and aphid infestation for different locations, viz. Bharatpur (27°12'N, 77°27'E), Hisar (29°10'N, 75°16'E), Pantnagar (29°N, 79°3'E), Morena (29°26'N, 78°E), Berhampur (24°6'N, 88°19'E) and Ludhiana (30°54'N, 75°48'E) in India were collected from published literatures for development of statistical models. Meteorological data used for forecasting were daily data on maximum and minimum ambient temperature (°C), morning and afternoon relative humidity (%) and bright sunshine hours, which were recorded at site-specific meteorological stations as per standard norms of World Meteorological Organisation (Ghadekar 2002). System used the weekly average of the five weather parameters.

Multiple step-wise regressions are powerful statistical techniques (Draper and Smith 1981) that is most widely used by forecasters till date. The method is typically for the data scenario available to estimate the average relationship between a dependent variable and two or more independent variables with regular data patterns. On the basis of historical data, correlation of timing of attack of *L. erysimi*, peak number of aphid and crop age at peak aphid population with weather variables were determined. Linear prediction model based on the weather parameters as independent variables and crop age at first appearance of aphid on crop, peak number of aphid on crop and crop age at peak aphid population as dependent variables were fitted by multiple step-wise regression. The models were developed in the following format:

$$Y = a_0 + \sum_{i=1}^{p} a_i z_i + \sum_{i \neq j}^{p} b_{ij} z_{ij} + e \quad (1a)$$

$$= a_0 + a_{maxtmp} z_{maxtmp} + a_{mintmp} z_{mintmp} + \ldots\ldots + a_{ws} z_{ws} + b_{maxtmp\ x\ mintmp} z_{maxtmp\ x\ mintmp} + \ldots\ldots + b_{bssh\ x\ ws} z_{bssh\ x\ ws} + e \quad (1b)$$

where $z_i = \sum_{w=1}^{f} r_{iw} x_{iw}$ (2a)

$$z_{ij} = \sum_{w=1}^{f} r_{ijw} x_{iw} x_{jw} \quad (2b)$$

with Y being dependent variable, x_{iw} the value of i^{th} weather parameter in w^{th} week, r_{iw} the value of correlation coefficient between Y and i_{th} weather parameter in the w_{th} week, r_{ijw} the correlation between Y and product of x_i and x_j in the w_{th} week, *p* the number of weather variables, *f* the week after sowing when predicted and *e* is the error term.

The location-specific models for crop age at first appearance of aphid on crop (Y_1), crop age at peak number of aphid on crop (Y_2) and peak population of aphid on the crop for the season (Y_3) for the locations Bharatpur, Hisar, Pantnagar, Morena, Berhampur and Ludhiana were derived as follows.

$$Y_1 = -112.91 + 0.02Z_{131} + 4.98\ Z_{11} \quad (R^2 = 0.71) \quad (3a)$$

$$Y_2 = 77.1 + 0.03Z_{121} \quad (R^2 = 0.63) \quad (3b)$$

$$Y_3 = 690.77 + 79.29Z - 0.019Z \quad (R^2 = 0.65) \quad (3c)$$

These site-specific models developed to predict the infestation of mustard aphid were validated and evaluated for four (2005–09) crop seasons at these locations and the software was devised till 2011.

The detailed software design starts from the identification of functional requirements of the system. It defines the requirements from the perspective of the users of the system based on our experience in past applications (Kumar *et al*. 2008). The design mainly describes the functional requirements such as weather data entry, model embedding, end-user forecast and graphic-user interface. The resulting system architecture was designed to develop an efficient rapeseed-mustard aphid forecast system as shown in Fig 1.

Weather data input management needed for forecast of aphid, site-specific models derived for mustard forecast and knowledge were integrated using LAMP technology for development of online web-based rapeseed-mustard forecasting system. Open source technology Linux, Apache, MySQL and PHP (LAMP) is cost-effective technology and dependent on choice of professional in the development of

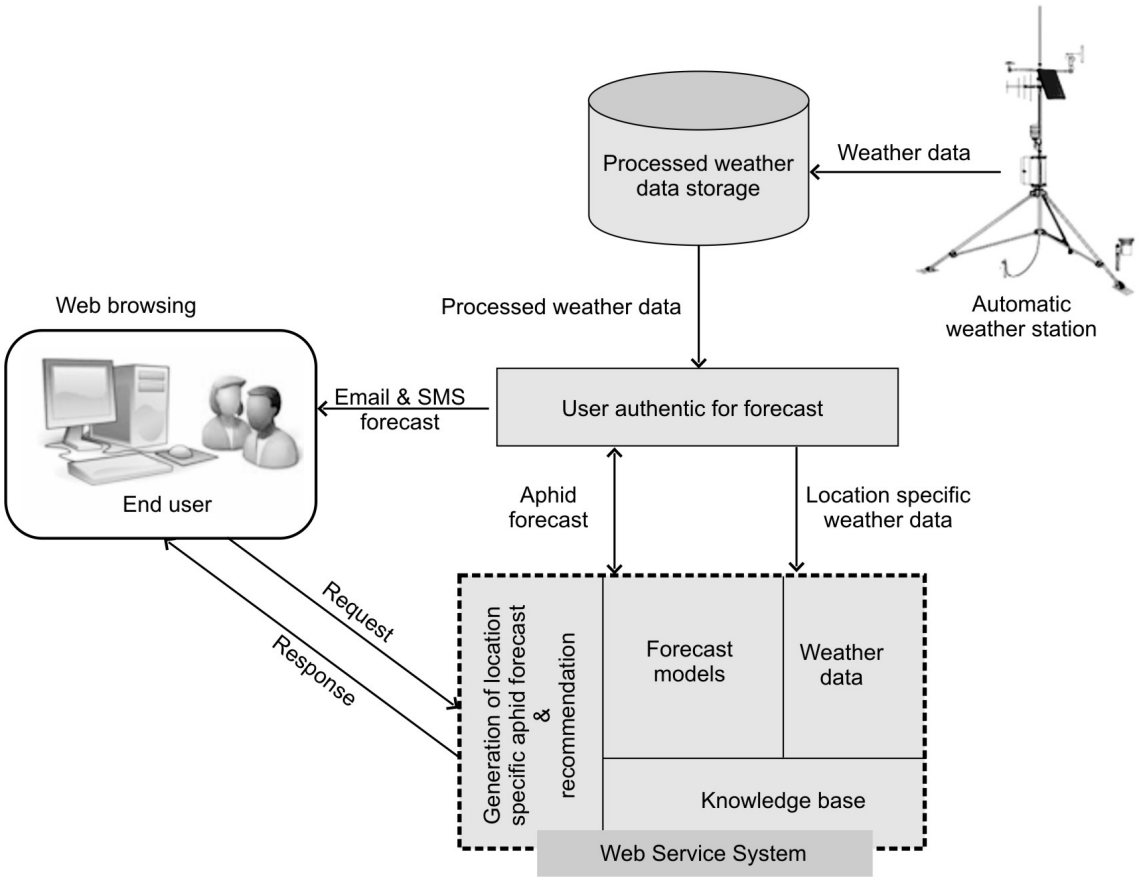

Fig 1 Overall aphid forecast system design architecture

data-driven web-based applications. The system operates on a server running Linux operating system. MySQL version 5.0.92 and Apache 2.2.19 were used for database management server and web server, respectively. PHP and Java script languages were used in programming applications (Kang *et al.* 2010). Location-specific forecast models have been coded in these languages and saved on server. Weather data acquisition and process is site-specific. The knowledge is prepared through the interaction with subject expert and consultation of published literature. After providing the input, the system integrates weather data, forecast model and knowledge base to generate forecast of mustard aphid on oilseeds *Brassica* crop for the particular site and season. System can be browsed over internet from any client machine having Internet Explorer, Netscape, etc. web browsers.

RESULTS AND DISCUSSION

Mustard aphid forecasting system is web-based and is available at http://www.drmr.res.in. The two modes of knowledge access in the present system are browsing and forecast. Information on a known species of mustard aphid can be accessed by browsing through the scientific name of the insect. The system includes detailed information about mustard aphid, favourable conditions, recommended and safe use of insecticides in the form of descriptive text, illustrations in a separate HTML (Hypertext Markup Language) and pdf pages, which can be viewed using the standard web browsers such as Internet explorer, Netscape, pdf reader, etc. (Fig 2).

Weather-based forecasting systems reduce the cost of production by optimizing the timing and frequency of application of control measures and ensure operator, consumer and environmental safety by reducing chemical usage (Kaundal *et al.* 2006). The principal use of this system, however, is to provide forecast of information about timing and quantity of aphid infestation well in advance.

The software is a user-friendly one. Users just have to feed the recorded weather variables prevailing in their areas, viz. weekly averages of temperature (maximum), temperature (minimum), relative humidity (morning), relative humidity (afternoon), and hours of bright sunshine for any set of six consecutive weeks from 40th to 50th week of crop season starting at week of sowing in the 'submit' form of the server (Fig 2). After submission of weather parameters, the software forecasts: (i) crop age at which mustard aphid first appears on the crop, (ii) peak number of aphid (aphid population) expected on the crop in the season, and (iii) crop age at peak number of aphid just by submitting the data (Fig 3). These

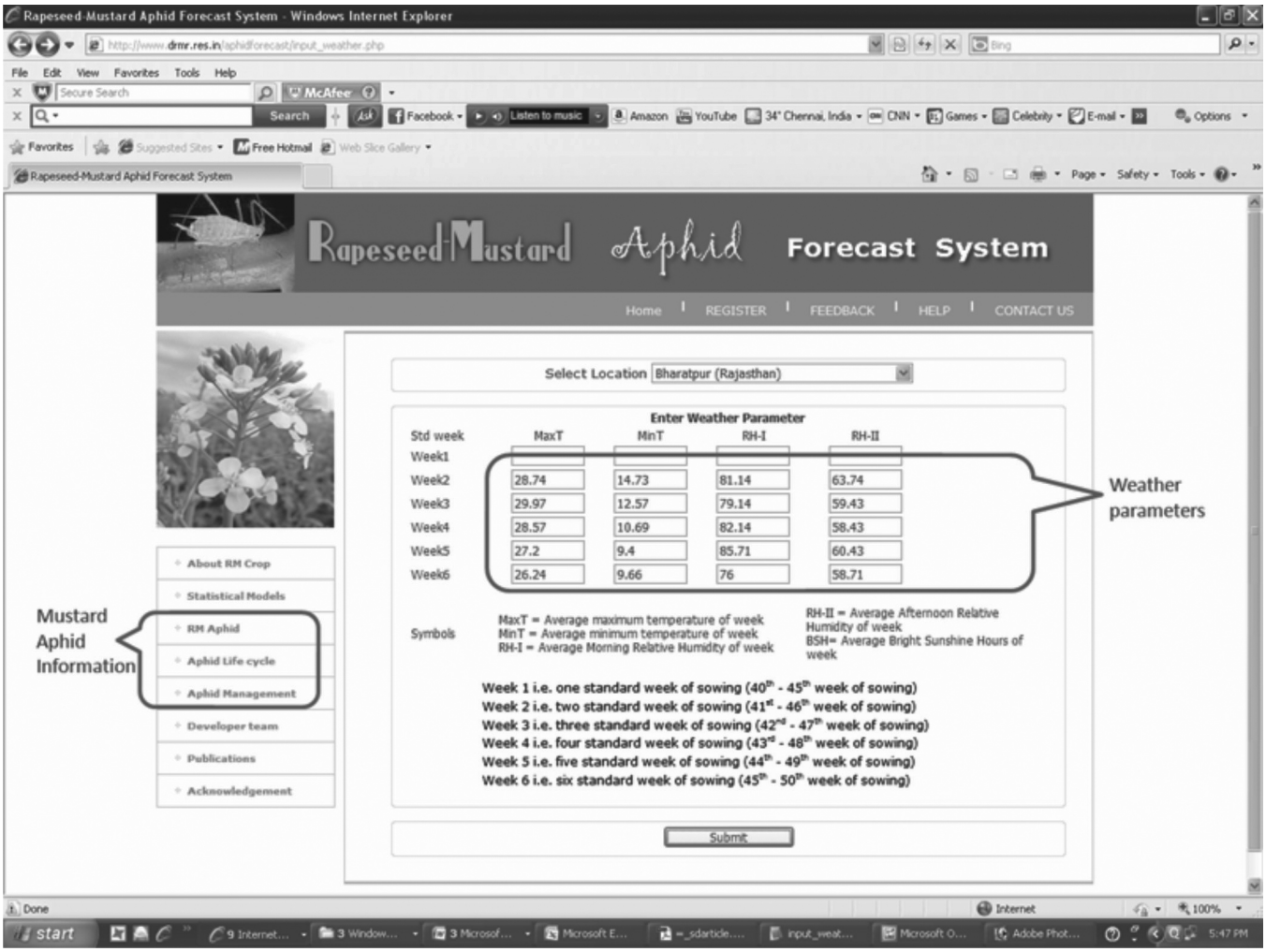

Fig 2 Browse aphid information & submit of weather parameter

models used in the software are advantageous over earlier ones (Kar and Chakravarthy 2000, Chakravarthy and Gautam 2003) as these take in to account several weather parameters and not just the temperature aspect. Further, these models cover the major locations of the oilseed *Brassica* growing regions of India that face onslaught of the aphid menace.

The output of the models is the mathematics of insect prediction. The system interprets the model output applying set rules and generates the recommendations for application of insecticides (Kumar *et al*. 2004, Pavan *et al*. 2011). It provides the recommendations for application of insecticides which aid in the decision making of extension personnel in providing agro-advisory (Fig 4). Importantly, in years of low aphid infestation, the system provides recommendation for only need-based or even avoiding insecticidal spray. System recommends the insecticides and the quantity required, that helps in environment-friendly cost-effective oilseed *Brassica* crop management, which includes aphid management.

Information dissemination is an important task. The software system generates location-specific forecast information and makes it available on the site. Anyone can forecast for their weather parameters for specific location using the system. Since the forecast is weather dependent, hence authorised person would be responsible to generate the forecast and make it available to end user. Forecast information can be sent to the user registered for the specific location by email or through SMS on mobile and location-wise forecast information can also be browsed from system website (Fig 5).

One of the challenges for rapeseed-mustard researchers, besides the development of theoretical mathematical equations integrating biology and climatology, is to provide online user-friendly web-based forecasting software for mustard aphid. In this study, we developed and implemented a web-based information system for rapeseed-mustard aphid forecast in India with a special consideration on practical use by extension personnel and crop growers. In addition, information on mustard aphid, ecological characteristics,

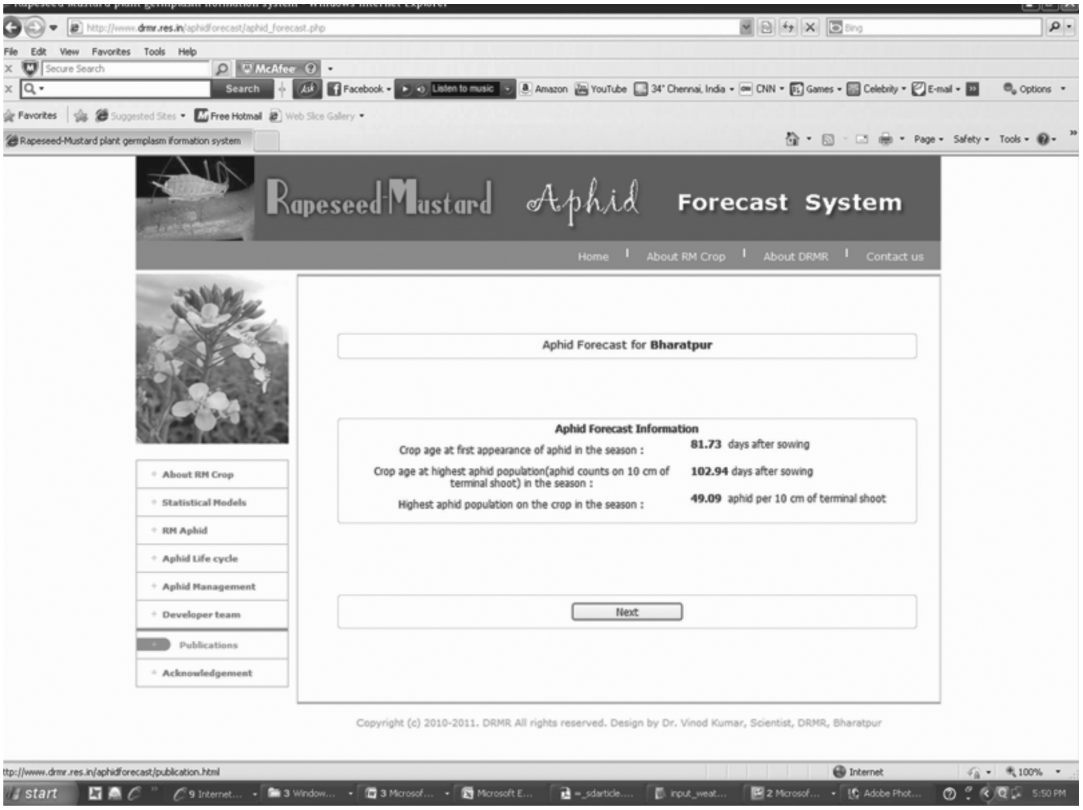

Fig 3 System forecast output results

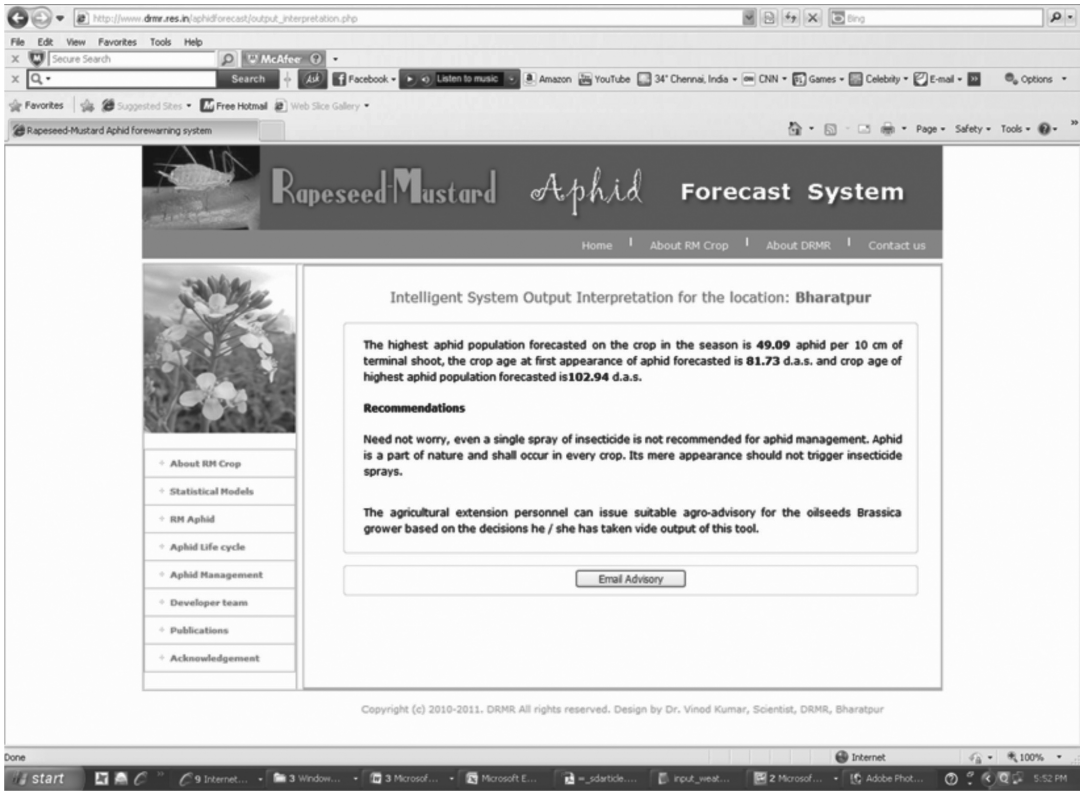

Fig 4 Interpretation and recommendation for management of aphid

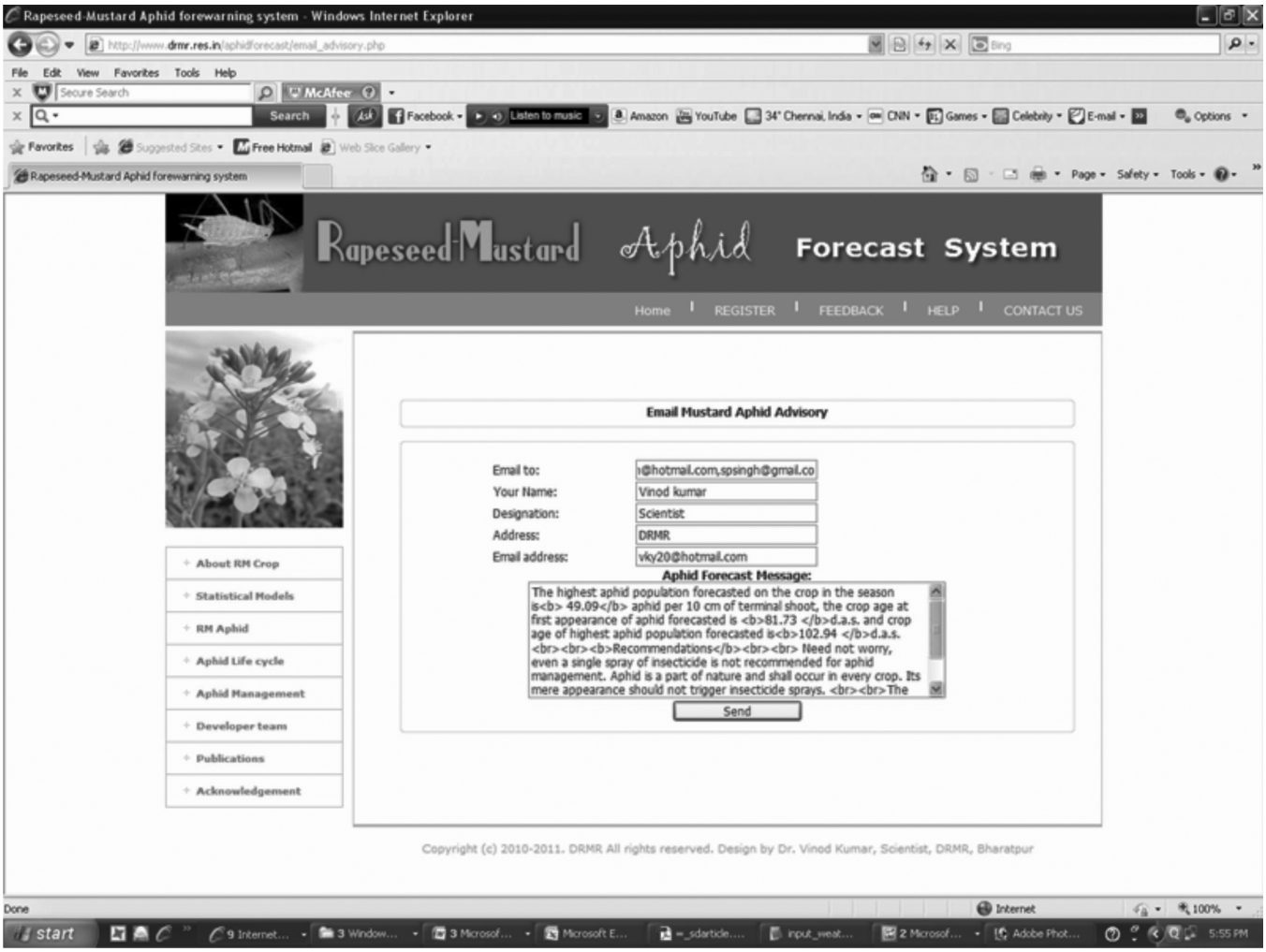

Fig 5 Send email of forecast results and recommendations

insecticides for aphid management and safe use of insecticides is available on the system to add value to the prediction for real-time agro-advisory. The major characteristics that make the information system practically useful to crop growers include site-specific easy user-friendly accurate aphid forecast, delivered by system interface well in advance of aphid arrival on crop. The accuracy is mainly dependent upon validity of aphid forecasting model and accuracy of weather data. The aphid forecasting model (Chattopadhyay *et al.* 2005), which has been tested at specific locations in India have been found acceptable in estimating infestation of mustard aphid on oilseeds *Brassica* crops. Accuracy of weather data can be assured by accurate measurement of weather conditions at standard meteorological observatories (Ghadekar 2002). Finally, this is a prototype system developed to forecast site-specific infestation of *L. erysimi* on oilseed *Brassica* in India and the concept could be repeated for other-sites and pests of oilseeds Brassicas as also in other crops, depending on availability of systematic data required for devising such models. The system has been developed using open source technology. Hence, user is not required to make any specific investment in terms of software / hardware for using the system. The system can be used on any machine having the browser and internet connectivity. Online evaluation of the system is in process and initial user response has been very positive due to effective forecast and the easy-user interface. Future work will continue to refine and augment the application in response to user-feedback and also introduce novel system for mustard aphid forecast.

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