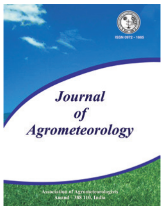

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Research Paper

Development of a decision support system for real-time forewarning of pests and diseases of different crops, for usability in Agromet Advisory Services

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ABSTRACT

Forewarning pests and diseases in real-time is one of the key components in Agromet Advisory Bulletin (AAB) of India Meteorological Department (IMD). In order to facilitate it, a comprehensive knowledge databank on weather-based pests and diseases of crops were collected to develop a decision support system (DSS) comprising of algorithms on thumb rules of pests and diseases prediction of major crops of *kharif* and *rabi* seasons. The algorithm was validated with the real-time observation on pests and diseases of five crops (rice, sorghum, chickpea cotton and maize) during *rabi* 2021-22 and *kharif* 2022 seasons, grown over 12 District Agromet Units (DAMU) locations across the country. The DSS upon validation, yielded prediction of pest diseases with correctness varying between 33 to 100 percent across the crops and locations. The forecast accuracy was more reliable during *rabi* season in comparison to *kharif* season crops/pests/diseases. For effective operationalization of weather based heuristic models and thumb rules, these have to be tested and validated in all the agroclimatic zones of the country.

Keywords: Decision support system, Pests, Diseases, Forewarning models, Thumb rules

Crop loss due to insect pests, diseases and weeds vary from 10 to 30% and at an average loss of 20 %, the loss in terms of monetary is about Rs. 1,40,000 crores/annum. Yield losses are estimated to be higher for fruits and vegetables (4.6-15.9%), followed by pulses (6.4-8.4%), cereals (4.7-6.0%) and oilseeds (3.1-10%) not to discount post-harvest losses due to insects and diseases that are high especially perishable commodities (Vennila, *et al.*, 2020). The yield losses due to pest, disease and weed in eight crops indicated that pests accounted for pre-harvest losses of 42% of the potential value of output, with 15% attributable to insects and 13% each to weeds and pathogens with an additional 10% of the postharvest losses (Geethalakshmi, *et al.,* 2019).

Forewarning is an essential component of integrated pest management and weather-based forecasts of insect pests provide information on the timing and intensity of the pest infestation beforehand that guides growers to take-up timely, cost-effective and eco-friendly protection measures in addition to enhanced resilience to climatic variability (Chattopadhyay, 2016). Weather based pest and disease forewarning provides opportunity to farmers for preparedness and for taking timely action to apply bioagents and pesticides which ultimately cut down the cost of production (Singh *et al*., 2018). A holistic approach of crop health management within the ambit of integrated pest management is promoted for crop protection against insects and diseases in our country (Vennila *et al.,* 2020). Early forewarning of crop pest based on weather variables provides lead time to manage impending pest attacks that minimize crop loss, decrease the cost of pesticides and enhance the crop yield (Naranammal and Krishna Priya, 2024).

Thumb rule-based and empirical model-based predictions for many major pests and diseases have been developed by various research institutes of Indian Council of Agricultural Research (ICAR) like ICAR-NCIPM New Delhi, ICAR-CPRI Shimla and ICAR-DRMR, Bharatpur. Besides, several isolated works on forewarning of different pests and diseases have been developed for crops like mustard-rapeseeds (Chakravarty and Gautam, 2004; Yadav *et al.,* 2022; Mehnaj *et al.,* 2017), soybean (Patel *et al.,* 2019), rice (Thapa *et al.,* 2025; Reddy *et al.,* 2006) and many more. The remote sensing based forewarning models have also been attempted (Tiwari *et al.,* 2025). However, there is a need to combine all the existing weather-based models of pests/ diseases forecast in agro-advisory bulletins

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(AAB), which can offer a huge scope to benefit farming community, for undertaking timely plant protection measures.

In view of this, an attempt has been made to develop a dynamic pest-disease forewarning decision support system (DSS) incorporating thumb rules documented by various institutes across the country to facilitate pest-disease forewarning in real-time through AAB utilizing IMD medium range weather forecasts. These were validated over various DAMUs (District Agromet Field Units) of IMD, for various diseases and pests of selected crops, for its further operationalization.

MATERIALS AND METHODS

Development of forewarning system

In order to develop a decision support system for forewarning of pest and diseases, a large dataset on pest and diseases of different crops and the thumb rules developed by different centres, were collected. The reports and publications of ICAR-National Centre for Integrated Pest Management (NCIPM) New Delhi (Vennila *et al.,* 2020; Vennila *et al.,* 2016) and the thumb rules documented by Tamil Nadu Agricultural University (TNAU) Coimbatore (Geethalakshmi *et al.,* 2019) served as prime source for development and validation. A dynamic weather-based pest/ disease forewarning system (Fig. 1) was developed for incorporating the pests/ disease models (thumb rules) for operational real-time forewarnings and its usage in AAB, using python computer-based language. The system includes database of nine *rabi* crops (rice, wheat, chickpea, mustard, sorghum, safflower, potato, tomato and onion) having eight insect pests and 25 diseases while for seven *kharif* crops (rice, maize, cotton, mango, tomato, sorghum and pearl millet) 22 insect pests and 27 diseases. The input uses one week's daily weather parameters of maximum temperature (Tmax) and minimum temperature (Tmin), rainfall (RF), maximum relative humidity (RHmax) and minimum relative humidity (RHmin), cloud cover (CC), wind speed (WS) and wind direction (WD). The developed decision support system (DSS) comprises of separate modules for each insect pest and disease under each of the growing season. Each module of insect pest/ disease, displays an image and information related to its pest infestation/ disease symptom. The DSS was submitted to Agromet Advisory Service Division of India Meteorological Department, for the purpose of crop pest and disease prediction and its subsequent incorporation into AAB. So far, it is under experimentation purpose, and was made available to IMD's AMFUs and DAMUs.

Input requirements and output

The user can select a growing season (*Rabi/Kharif*), crop, pest/ disease, Indian political state and station. List of state names, station names and codes are provided in the software combo box. These station names correspond to the nearby AMFUs (Agromet Field Units)/ DAMUs. The user then needs to browse their input/ output folder location and choose the input excel file of station of their choice and select the date of start of simulation which is the last date of weather data input. Models of various pests and diseases with prediction capability of one week lead time are incorporated into the DSS. The exception is for *Macrophomina* root rot of Safflower model, which require two weeks' (at least fourteen (14) days') daily weather data as input excel file, prior to the 'start of simulation' date, to predict the disease status. Hence, for all the models, seven days daily weather data should be made available as input excel file prior to the 'start of simulation' date. The required number of weeks of pest/ disease prediction needs to be entered as input. The input excel file must be named as station code (IMD station codes). A detail instruction of data format is also provided. An excel output file is generated in the same folder of the input file.

Validation

The experimental DSS thus developed, was made available to AMFUs and DAMUs for necessary real-time validation and documentation, after imparting training. Depending upon data availability, the pests and diseases observed on crops cultivated at respective DAMUs were validated in real-time in *kharif* (2022) and *rabi* (2021-2022) seasons. The validation of the forewarning system on real-time basis was done with near-real-time observed weather data and Tuesday and Friday weather forecasts used in AAB. For Tuesday and Friday forecasts, the first two (2) dates in input weather data file are realized weather data of up to those dates, while the next 5 dates are taken as weather forecast data, as disseminated in AAB, thus filling 7 days input data. The insect pest disease data were collected using the surveillance method following the recommendations provided by ICAR-NCIPM, New Delhi

The validation metric used is per cent correctness.

$$\text{Per cent correctness} = \frac{\text{Number of weeks of correct prediction}}{\text{Total number of weeks}} \times 100$$

In *kharif* (2022) season, maize stem borer, rice blast, rice brown spot, rice yellow stem borer, bacterial leaf blight, rice leaf hoppers, rice sheath rot, cotton thrips, cotton whitefly and cotton aphid were validated. The intensity of pest measured in above and below Economic Threshold Level (ETL) categories and disease severity scales (Table 1), were considered for validation. In *rabi* (2021-2022) season, chickpea *Fusarium* wilt, rice yellow stem borer and sorghum ergot were validated. These were given scales between normal, mild, moderate, severe and very severe, as recommended by ICAR-NCIPM manual (Vennila *et al.,* 2020; Vennila *et al.,* 2016). The weekly predictions in the DSS were as per these scales/ intensity markers, which were validated by ground survey and thereby its per cent correctness was computed. The number of weeks wherein observed intensity of pest/disease is the same as the forewarned is taken up and divided by the total number of weeks considered, to compute per cent correctness. The ETL of pests/ diseases and the conducive weather or proxy indicators used as thumb rule for all the validated pests/ diseases are presented in the Table 1. These heuristic rules, comprising of a combination of various weather parameters, were used in pest/ disease status prediction.

RESULTS AND DISCUSSION

Twelve DAMUs stations, where validation data were collected, are Valsad (Gujarat), Khandwa (Madhya Pradesh), Haveri (Karnataka), Gaya (Bihar), Banka (Bihar), Angul (Odisha), Rayagada (Odisha), Khammam (Telangana), Jharnapani

Table 1: Vulnerable stages of crop, ETL, and risk prone zones and the conducive weather or proxy indicators for pests and disease selected for validation of DSS

S. No	Crop	Pest/ Disease	Vulnerable crop stage	Disease severity/ ETL of pest	Risk prone areas	Proxy indicators used as thumb rule
			Rabi			
1	Chickpea	*Fusarium* wilt	Seeding and flowering	11-25 % leaves and branches show chlorosis with slight vascular discoloration	MP, MH, GJ, Telangana, Karnataka, UP, Bihar	Sandy soil, Tmean >25°C
2		*Botrytis* gray mold	Flowering and podding	Water-soaked lesions and soft rotting of 11-25% of tender leaves and shoots	Eastern UP, Bihar, WB and UK	RHmean >90%, Tmean 20 to 25°C
3	Rice	Yellow stem borer	Tillering to maturity	Dead heart and White ear; 5-10% dead hearts, 1 egg mass /m^2 or 1 adult moth /m^2	South Peninsular India, Orissa, MP, GJ, Assam, WB and MH.	Tmin < 23 °C, Tmax 28 to 35°C, RF 0 to 2.8mm/ week, RHmean 60 to 67%
4	Sorghum	Ergot	Flowering to ear head maturity	>=11 spikelet damage (% infected)	MH, Karnataka, AP, GJ, TN, UP	Week long drizzle or high RF, Tmean 19°C, Wind Currents
			Kharif			
5	Maize	Stem borer	Seedling to reproductive	10% dead hearts.	Maize growing states	Tmean 20-30°C, RHmean 40-70%, WS <5km/h, RF <30mm/week
6	Rice	Blast	All stages	Infected leaf, collar, node, neck. Mid tillering: 5-10% disease severity. Panicle initiation to booting: 2-5% leaf area damaged. Flowering and after: 5% leaf area damaged or 2% neck blast	Rice growing states	Tmean 20-30°C, RHmean >90%, WS <5km/h, RF 30-50 mm/week
7		Brown spot	Seedling to milking	2-5% tillers affected		Tmean 20-30°C, RHmean >70%, WS >5km/h, RF 30-50 mm/week
8		Yellow stem borer	Tillering to reproductive stages	1 egg-mass/m^2		Tmean 20-30°C, RHmean >70%, WS <5km/h, RF 0-30 mm/week
9		Bacterial leaf blight	Seedling and vegetative stages	2-3 infected leaves/m^2		Tmean 20-30°C, RHmean >70%, WS <5km/h, RF >50 mm/week
10		Leaf hoppers	Seedling to reproductive stages	Brown plant hopper /WBPH: 10-15 hoppers/hill		Tmean >30°C, RHmean >70%, WS <5km/h
11		Sheath rot	Panicle initiation	Lesion length 2-3 mm on sheath and 3-5 infected plants/ m^2		Tmean 20-30°C, RHmean >90%, WS <5km/h, RF 30-50 mm/week
12	Cotton	Thrips	Vegetative and reproductive stages	8-10 thrips per leaf	Cotton growing states	Tmean >30°C, RHmean 40-70%, WS >5km/h, RF 0 mm/week
13		Whitefly	Reproductive stage	5 adult/nymph per leaf		Tmean >30°C, RHmean >70%, WS >5km/h, RF <30 mm/week
14		Aphid	Seedling and vegetative stages	10/leaf or on visible damage		Tmean 20-30°C, RHmean 40-70%, WS >5km/h

Sources: Vennila *et al.,* (2016; 2020); Geethalakshmi, *et al.,* (2019); Bhattacharjee *et al.,* (2019); Safdar *et al.,* (2019); Chakraborty and Ghosh, (2010)

(Nagaland), Kolasib (Mizoram), Jammu (Jammu and Kashmir) and Parbhani (Maharashtra) (Table 2). The DSS was distributed to the AMFUs and DAMUs, for real-time validation for pest/disease of different crops. Centres collected the pests and diseases of the crops grown at the station. Observations were recorded as per guidelines provided by ICAR-NCIPM New Delhi. The output consisting of

Table 2: Validation reports of *rabi* 2021-22 and *kharif* 2022 seasons

Pest/ Disease	DAMU station	Forecast accuracy	Per cent correctness
	***Rabi* 2021-22**		
Chickpea *Fusarium* wilt	Valsad	14/18	77.8
	Khandwa	1/1	100
	Haveri	9/11	81.8
	Gaya	15/17	88.2
	Banka	5/11	45.5
	Total	44/58	75.9
Sorghum ergot	Haveri	11/11	100
	Khammam	7/7	100
	Total	18/18	100
Rice yellow stem borer	Angul	9/9	100
	Rayagada	4/4	100
	Khammam	5/6	83.3
	Total	18/19	94.7
	***Kharif* 2022**		
Rice blast	Jharnapani	0/1	0
	Kolasib	0/1	0
	Jammu	0/2	0
	Total	0/4	0
Rice brown spot	Jharnapani	0/1	0
	Kolasib	0/1	0
	Total	0/2	0
Rice yellow stem borer	Jharnapani	1/1	100
	Kolasib	0/1	0
	Total	1/2	50
Rice bacterial leaf blight	Kolasib	1/1	100
	Jammu	0/2	0
	Total	1/3	33.3
Rice leaf hoppers	Kolasib	1/1	100
Rice sheath rot	Kolasib	1/1	100
Cotton thrips	Parbhani	3/9	33.3
Cotton whitefly	Parbhani	9/9	100
Cotton aphid	Parbhani	5/9	55.6
Maize stem borer	Jammu	3/3	100

weekly predictions of the status of pest/disease is based upon the previous week's state of weather. The thumb rules for thresholds of conducive weather for severity of different levels of ground survey (normal, mild, moderate, severe and very severe) method and its categorization were also directed by ICAR-NCIPM (Vennila *et al.,* 2020).

During *rabi* season, three crop pest/diseases were validated at eight locations. Table 2 shows that the chickpea *Fusarium* wilt, were recorded at five stations. The overall accuracy was found to be about 76 per cent across the locations. In case of sorghum ergot both the stations showed 100 per cent forecast accuracy. Rice yellow stem borer observations were recorded at three stations and the overall forecast accuracy was 95 per cent. Thus, it shows that during *rabi* season, the forecast accuracy was high. However, it may be noted that only three crop/disease of *rabi* season were validated. Validation of DSS needs to be done for all the incorporated diseases and pests of *rabi* season crops.

For *kharif* season crop/pest/diseases, the DSS was validated in real-time at five locations for pest/diseases viz. maize stem borer, rice blast, rice brown spot, rice yellow stem borer, rice bacterial leaf blight, rice leaf hoppers, rice sheath rot, cotton thrips, cotton whitefly and cotton aphid (Table 2). It may be noted that the incidence of pests and diseases of rice crop were mild which could not be captured by the DSS. The insect pests of cotton and sorghum were accurately forecasted ranging between 33 to 100 percent. This emphasizes that the validation experiment should be carried out in 2-3 seasons at more stations to improve the DSS.

CONCLUSION

The decision support system (DSS) developed using large datasets across the country was validated for selected crop/pest/diseases of selected locations during *kharif* (2022) and *rabi* (2021-22). The results revealed encouraging results with varying correctness from 33 to 100 per cent. However, for effective operationalization of weather based heuristic models and thumb rules, this system has to be tested and validated in every agroclimatic zones of the country for all the major crops for at least three consecutive seasons. The DSS proves to be a good initiative in unifying all the heuristic rules developed so far by researchers, for the benefit of a farming community, by means of weather-based Agro-advisory bulletins.

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Author Contribution Declaration: **Mehnaj T. A.**: Developed the software (DSS), Analysis work and validation tasks. Provided training to IMD AMFUs and DAMUs. **K. K. Singh:** Monitoring, Principal Investigator of the project GKMS, **S. Goroshi**: Coordinated IMD, New Delhi, and ICAR- NCIPM, New Delhi.

Data availability declaration: Weather data for validation can be made available by request from IMD NDC portal, https://dsp.imdpune.gov.in/, while weather forecast for forewarning pests and diseases can be found in AAB of the station available at https://mausam.imd.gov.in/imd_latest/contents/agromet/advisory/benglishmain.php/. The developed DSS PD v.4 is currently experimental.

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