Late Blight Forecast Using Mobile Phone Based Agro Advisory System

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Abstract. The late blight disease is the most common disease in potato, which is caused by the pathogen *Phytophthora infestans*. In this paper, a novel method to collect symptoms of the disease, as observed by the farmers, using a mobile phone application has been presented. A cumulative composite risk index (CCRI) obtained from more than one existing disease forecast models is validated from the actual late blight queries received from the farmers. The main contribution of the paper is a protocol that combines the symptoms based diagnostic approach along with the plant disease forecasting models resulting in detection of Potato late blight with higher accuracy. This in turn reduces the disease risk along with avoiding the unnecessary application of fungicide.

1 Introduction

This paper focuses on timely detection of the Late Blight in Potato crop under the Indian climatic conditions. About 80% of the potato farming in India is done in winter season, a time quite ideal for the pathogen *phytophthora infestans*, the agent responsible for Late Blight, to infest. Several models [1], [2], [3], [4], [5], [6], [7] have been developed for the prediction of a Late Blight attack based on weather parameters. Some of these models take into consideration atmospheric parameters such as temperature, humidity and rainfall, to decide the likelihood of a late blight attack. The *Ullrich* [4] and *Fry* [1] models utilizes hourly temperature and hourly humidity in order to compute a risk value. A cumulated risk value is computed in Ullrich's model, by summing the risk value for each day provided the daily risk is more than a particular threshold. The prediction for late blight is then made when this cumulated risk value crosses an assigned threshold. To calculate its 'blight unit', Fry's model classifies the temperatures broadly and then declares a unit based on the number of hours the humidity levels cross the threshold. *Winstel* model [5] issues a warning whenever the average temperature is within a certain range and hours of relative humidity greater than 90% cross a threshold of 10 hours. *Wallin* model [2], [3] provides a severity value based on hourly temperature and humidity measurements and suggests

that the disease risk is high on 7-14 days after the cumulative severity value had exceeded the assigned threshold.

On the other hand, the diagnostic method to detect the late blight is by observing the symptoms [8], personally, on the crop.

In this paper we present a disease forecast protocol based on a mobile phone based agro advisory (mKRISHI) system. The key idea is to combine the disease risk obtained from various models and the knowledge of symptoms obtained from farmers input on mobile phone, to determine the appropriate doses of the fungicide. The proposed protocol minimizes the disease risk along with the farming losses.

2 The mKRISHI Based Late Blight Forecast and Diagnostic Protocol

Mobile phone based agro-advisory system (mKRISHI) [9] can provide expert's advice related to various domains such as farming, education, finance etc., to the rural masses. A simplified schematic of mKRISHI is shown in Fig. 1. A farmer can ask any query to the expert in the form of voice, text and images using the mKRISHI mobile client application on his mobile phone. Further, atmospheric, soil and plant related parameters, observed by the weather station deployed in the farm, are also made available to an expert for detailed investigation.

Here, we present a novel protocol to combine the existing forecast models and diagnostic techniques using the mKRISHI framework.

Fig. 1. A Simplified Schematic of mKRISHI

2.1 The Proposed Protocol

Cumulative Composite Risk index. Some of the existing Late Blight disease forecast models were discussed in Section 1. Each disease forecast model m ($m = 1, 2, \dots, M$) has been assigned a weight ' W_m '. Let r_i^m be the risk value shown by the model m on the i th day, and r_{max}^m be the maximum possible risk value corresponding to the model m . The composite risk index R_i for i th day, considering all M models is given by

$$R_i = \sum_{k=1}^{k=M} \eta_i^k W_k \quad (1)$$

where, $\eta_i^m = r_i^m / r_{max}^m$. The composite risk index is then accumulated over last N days to obtain a Cumulative Composite risk index (CCRI). So, for any i th day, the Cumulative Composite Risk Index C_i is given by

$$C_i = \sum_{j=i-N+1}^{j=i} R_j \quad (2)$$

where, N depends on models selected to obtain composite risk index and the region of application.

Protocol. The CCRI (C_i) is compared with lower and higher thresholds T_L^C and T_H^C , respectively, ($T_H^C \geq T_L^C$) to determine the appropriate doses of fungicide.

- **High Disease Risk** ($C_i > T_H^C$)

If the high disease risk is observed and if the fungicide has not been applied in the past T_{ED} days, then an alert message is sent to the farmer, prompting for the application of fungicide. Here, T_{ED} is the duration for which the applied drug is effective on the farms. According to the standard treatment procedures of Late Blight, this period is usually atleast 5 – 6 days [6], [1]. In our field trials, the agriculture experts were found to recommend the application of fungicide after 10 days from the date of application of the previous dose. Reuse of fungicide in T_{ED} days could be *harmful* in terms of higher residues and *unnecessary* in terms of cost.

- **Moderate Disease Risk** ($T_L^C < C_i < T_H^C$)

If the moderate disease risk is observed and if the fungicide has not been applied in the past T_{ED} days, then after a period of δ days, the farmer is prompted on his mobile phone seeking the symptoms of Late Blight [8], as observed by him on the farms. Here, δ is the time interval between the risk shown by the models and the appearance of the symptoms. An estimate of δ can be obtained by using an adaptive scheme discussed in the following part of this section. The queries asked to the farmers to obtain the knowledge of symptoms of the disease may have binary answers. This enhances the usability and minimizes the communicated overhead. If the responses from the farmer confirms the attack of late blight, then the farmer is prompted for

the spray of appropriate fungicide. Otherwise, the queries are sent again on daily basis for the next few days. The number of days for which farmer should be queried depends on the value of δ chosen and the models considered for evaluating composite risk index.

- **Low disease Risk** ($C_i < T_L^C$) If the disease risk indicated by C_i is low, then no action needs to be taken.

Adaptive Evaluation of Parameters

Here, we provide a description of the adaptability of the scheme with respect to unknowns used in the proposed protocol. The detection of symptoms, is tentatively 3–7 days after inoculation ([10]). For the first time, the queries to observe the symptoms can be sent 3 days ($\delta = 3$) after the moderate disease risk is indicated by C_i . Further, δ can be adapted based on the received responses from the farmer. Let γ be the percentage of queries with positive responses (symptoms confirming the disease) from a farmer. For each farmer, ' γ_{min} ' and ' γ_{max} ' are assigned, such that if there is a positive response to more than γ_{min} % of the queries and less than γ_{max} % of the queries, then the value of $\delta = 3$ is kept unchanged. If more than γ_{max} % of positive responses are received then next time the queries shall be asked a day earlier ($\delta = \delta - 1$). If less than γ_{min} % of the queries come in with a positive response then the queries are sent with a delay of one day ($\delta = \delta + 1$). However the time interval δ is not altered if doing so causes its value to exceed the stipulated limits. The limits are applied to make sure that the value of δ does not become too large to prevent the early detection or too small to increase the overload.

A weight W_m assigned to each model m , required to evaluate composite risk index, can be adapted over seasons of farming considering the difference between the composite risk values with the actual disease occurrences on the field. The values of N , T_L^C and T_H^C can also be fixed based on the results obtained by this scheme for the previous seasons and comparing the prediction dates with time of attacks.

3 Evaluation of Models

In this Section, we present the results obtained from disease forecast models, Ullrich and Schrodter [4], Wallin [3], [2], Fry [1] and Winstel [5], when applied to the data obtained from the mKRISHI weather station for the last farming season at Aligarh district, India. The hourly data of temperature and relative humidity from 16th to 27th of November and 1st to 8th of January, has been used to evaluate the Late Blight disease risk obtained from these models. Fig. 2 presents the binary disease risks (after quantization) by all models.

In the month of November, all the four models show strong correlation in disease risk indication, particularly on the 20th and 27th of November. Further, on 16th and 21st of November, Fry and Winstel indicated a disease risk. It was observed that Fry and Winstel gave indications of viable days of late blight inoculation for more number of times than Ullrich and Wallin models in November. In the first week of January, Ullrich-Schrodter, Wallin and Fry models depicted

Fig. 2. Binary Late blight disease risks by all four models and Late blight disease queries asked by farmers in the month of November and January

Fig. 3. Late blight disease queries asked by farmers in the month of November and January

the disease risks consistently. In Winstel’s model, only the first phase has been implemented to obtain the likelihood of the initial attack. Thus no attack has been observed for Winstel model in the month of January. Fig. 3 presents the number of queries asked by the farmers using the mKRISHI application in the months of November and December. It shows that there were queries concerning late blight attack during the 3rd week of November 2008 and 1st week of January 2009. This validates risk indications obtained by the models in those weeks. Fig. 4 shows images of the crop sent by the farmers along with the queries which further confirm a Late Blight attack.

Fig. 4. Images received from the farmers indicating Late Blight attacks. (a) Query id: 1621, Dated: 2nd Jan 2008 (b) and (c) Query id: 1309, Dated: 25th Nov 2008.

4 Conclusion

The mKRISHI based Potato Late Blight forecast protocol has been proposed by making a conjunctive use of existing disease forecasting models and symptoms based disease diagnostic procedures. Towards this end, we have implemented four late blight disease models in Indian scenarios by using the data obtained from mKRISHI weather station. The results obtained were then validated using the actual *Late Blight queries* (in the form of text, voice and images) that were sent by the farmers using mKRISHI application. We proposed a protocol, which confirms the disease symptoms from the farmers by asking them simple questions having 'yes/no' (binary) responses. This minimizes false alarm and hence reduces the amount of fungicide application if the computed disease risk is moderately high. Further, the losses are reduced by alerting the farmers immediately if the risk indicated by the models crosses certain higher (critical) threshold.

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References

1. Fry, W.E., Apple, A.E., Bruhn, J.A.: Evaluation of potato late blight forecasts modified to incorporate host resistance and fungicide weathering. *Phytopathology* 73, 1054–1059 (1983)
2. Wallin, J.R.: Summary of recent progress in predicting the late blight epidemics in unitedstates and canada. *American Potato Journal* 19, 306–312 (1962)
3. Wallin, J.R.: Forecasting tomato and potato late blight in the northcentral region. *Phytopathology* 41, 37 (1951)
4. Ullrich, J., Schrödter, H.: Das Problem der Vorhersage des Auftretens der Kartoffelkrautfäule (*Phytophthora infestans*) und die Möglichkeit seiner Lösung durch eine "Negativprognose". *Nachrichtenblatt Dt. Pflanzenschutzdienst(Braunschweig)* 18, 33–40 (1966)
5. Winstel, K.: Kraut- und Knollenfäule der Kartoffel – Eine neue Prognosemöglichkeit sowie Bekämpfungsstrategien. *Med. Fac. Landbouww. Univ Gent* 58/32b (1993)
6. Forrer, H.R., Gujer, H.U., Fried, P.M.: A comprehensive information and decision support system for late blight in potatoes. In: *Workshop on Computer-based Decision Support System (DSS) in Crop Protection*, Parma, Italy (November 1993)
7. Forsund, E.: Late blight forecasting in norway 1957–1980. *EPPO Bull.* 13, 255–258 (1983)
8. Henfling, J.W.: Late blight of potato: *Phytophthora infestans*. In: *Technical Information Bulletin 4*, International Potato Centre Lima, Peru (1987)
9. Pande, A., Jagyasi, B.G., Kimbahune, S., Doke, P., Mittal, A., Singh, D., Jain, R.: Mobile phone based agro-advisory system for agricultural challenges in rural india. In: *IEEE Conference on Technology for Humanitarian Challenges* (August 2009)
10. Seaman, A., Loria, R., Fry, W., Zitter, T.: What is late blight? In: *Integrated Pest Management Program*, Cornell University (2008), <http://www.nysipm.cornell.edu/publications/blight/> (last access September 2008)