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Research Article

Development of Disease Scoring System for Severity Analysis of Late Blight of Potato based on Image Processing Approach

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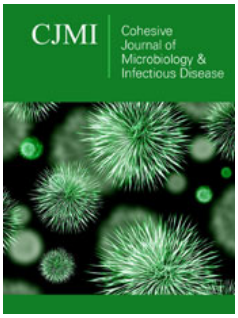

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Abstract

The severity for late blight disease of potato is quantified based on standard disease grading scale mainly by measure with the eye, which is greatly influenced by subjective factors and results in obvious error using Henfling disease estimation scale. The plant pathologists generally graded the late blight disease severity based on eye estimation for percent infected area according to the disease grading scale of Henfling. The disease scoring system is primarily the eye estimation methods and scores are varied among different pathologists. In this paper, an attempt has been made to develop image processing-based disease estimation for late blight of potato. The late blight affected portions of leaflets, leaves and whole plants have been evaluated using image analysis system. The percentages of affected areas have been calculated and scores have been assigned based on proposed scale. The assigned scores have also been verified from several plant pathologists based on Henfling's disease scale. The gap of disease intensity variation between pathologist's evaluation and image processing system has been fine-tuned by modification of the scale and finally the accuracy of scores estimation based on proposed image analysis system is 85% and could be effectively exploited for late blight of potato disease estimation.

Keywords: Late blight of potato; Henfling Disease estimation scale for late blight; Image based disease estimation scale; Image analysis; Plant pathology

Introduction

Late blight, (Phytophthora infestans) is most devastating disease of potato worldwide with several instances of catastrophic extent with huge economic and humanitarian loss. Under cool night and warm day and extended wet condition, this pathogen sporulate profusely so that entire potato field can be destroyed in less than ten days. The average annual losses due to late blight was to 15% of total production in the country. Late blight results in global annual losses of potatoes that would be sufficient to feed anywhere from 80 to many hundreds of millions of people [1-10]. Global tuber yield losses were reported to be €12 billion [5]. The reasons for such losses are the manual observation of the disease in the potato field when the pathogen spread very fast so that the management become ineffective. Thus, quick and early detection of disease is an important landmark for successful management. Traditionally, plant disease severity is scored with visual inspection of plant tissue by trained experts. The inconsistent results on measurement of plant disease based on eye estimation hinders the decision support system of fungicidal management schedule of late blight of potato.

One alternative method is automatic prediction of disease intensity through image-based analysis so that farmers may be able to spray effective fungicides in proper time. With the population of digital cameras and the advances in computer vision, the automated disease diagnosis models are highly demanded by precision agriculture, high-throughput plant phenotype, smart green house, and so forth. In recent years, spectral image-based disease severity scoring has gained new height, however, number of research works in this direction is meagre. Noticeably, deep learning convolutional neural networks, random forests and multilayer perceptron using band differences has been used to predict the level of infection of Phytophthora infestans on potato crops in Colombia [8-10]. Further, high-resolution portable spectral sensor was utilized to investigate the feasibility of detecting multi-diseased tomato leaves in different stages of crop growth, including early or asymptomatic stages [11-13].

The standard late blight disease scoring scale was developed by Henfling (1979). However, human eye estimation accuracy is variable. To incorporate the Henfling modified disease scoring system in image analysis-based system which will help in disease estimation without skilled personnel, it is necessary to standardize and humanize the scoring system so that the resulting disease severity will support the plant pathologist's and agriculturist's scoring. Moreover, computerized errors in image analysis, such as presence of colour variegation, dart, yellow halo etc. may also be considered and standardized in image analysis system so that the ultimate result will become reasonably accurate. Thus, aim of this research work has been finalized towards visual estimation of the disease symptoms by numerous subjects, standardization of the scoring scale and developed an image-based disease severity assessment scale for late blight of potato.

Materials and Methods

Collection of healthy and late blight affected potato plant image

The experiment was conducted District Seeds Farm "C" Unit of at Bidhan Chandra Viswasvidyalaya situated at Kalyani, Nadia, West Bengal, India images of symptomatic leaves were captured at different day light using DSLR camera. To remove the influence of soil colour, which is difficult to differentiate from dry potato leaves, one white A4 paper was placed under leaflet, leaf to cover the soil under tree before capturing pictures. Many pictures were captured for single leaflet, leaf, and whole plant from top and two sides keeping almost equal distances, placing on A4 white paper beneath (Figure 1), and pictures with shadow, improper lighting (blurred images) and with unwanted leaflets and excessive noise were discarded.

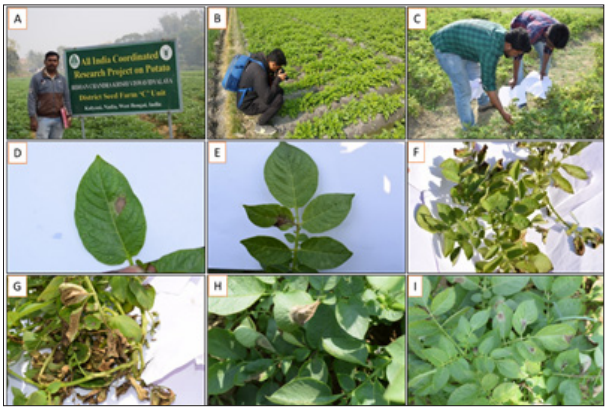

Figure 1: Field view of the experiment conducted in District Seeds Farm "C" Unit of at Bidhan Chandra Viswasvidyalaya (A-C), representative pictures of the leaflet (D), whole leaf (E) and potato plant (F-I).

Segmentation of late blight affected area at leaflet

D**isease rating scale and affected leaflets:** Disease rating scale plays important role to measure the disease intensity. Generally, the healthy leaves are assigned scale as '0' and dry leaves or plant are assigned by the maximum number with '9'. The scores between 0 and 9 are divided into either 1,3,5,7 or 1,2,3,4,5,6,7,8 scales. The score is assigned by the plant pathologist based on their eye estimation. The percentage of the affected area and their scores based on the plant pathologist eye estimation has shown in the Figure 2.

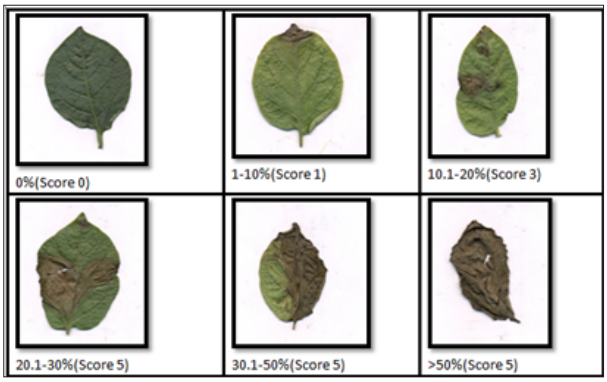

Figure 2: Percentage of affected potato leaflets and disease rating scores

K-means clustering: k-means clustering is one of the classical approach to solve the clustering problem. Main objective of the algorithm is to choose k-number of cluster centroid in such a way that each data point belonging to a given image data set and associate it to the nearest center [12-15]. This evaluation has made by Euclidean distance metric. The algorithm aims at minimizing

an objective function know as squared error function given by equation 1.

$$J = \Sigma_j^k =_1 \| x_i^{(j)} - c_j \|^2 \quad (1)$$

'$||x_i - v_j||$' is the Euclidean distance between x_i and v_j.

'c_i' is the number of data points in ith cluster.

'c' is the number of cluster centers.

Late blight affected image processing and score assignment: An algorithm has been developed to identify the actual disease affected area of the potato leaflet images. The algorithm has been taken the RGB potato images with white background. The actual affected area has been segmented using k-means clustering. Finally, percentage of affected area has been calculated from each leaflet, leaf or plant. Based on this percentage value, a disease score has been assigned consulting with disease rating scale. Details steps has been described using flowchart in Figure 3. In individual leaflet, the leaflet image with white background has been preprocessed. In pre-processing, the all-leaflet pictures have been resized into 1000×1280 pixel for making all pictures in same size. The unwanted portion i.e., outside of white A4 paper has been removed to keep whole background white. The leaflet has been segmented from white background and the affected portion of leaflet due to late blight has been segmented in each leaflet using k-mean clustering method [6-10]. The percentage of affected portion has been calculated with respect to whole leaflet and score has been generated using Henfling modified disease estimation scale for late blight of potato. The steps of segmentation are shown in Figure 4.

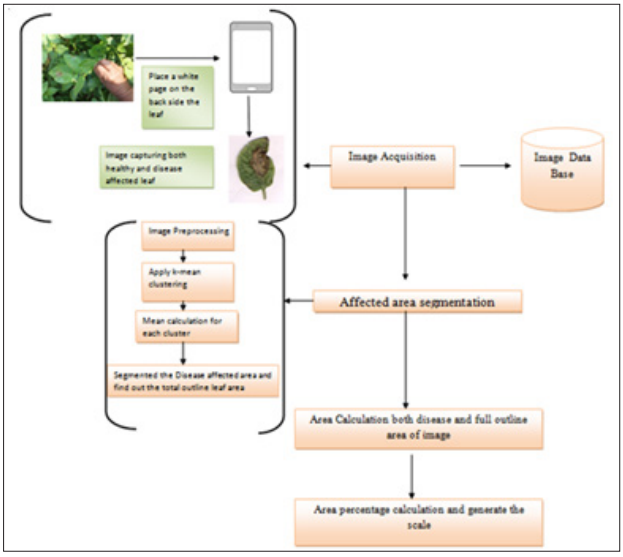

Figure 3: Flowchart of the processing affected images and score assignment

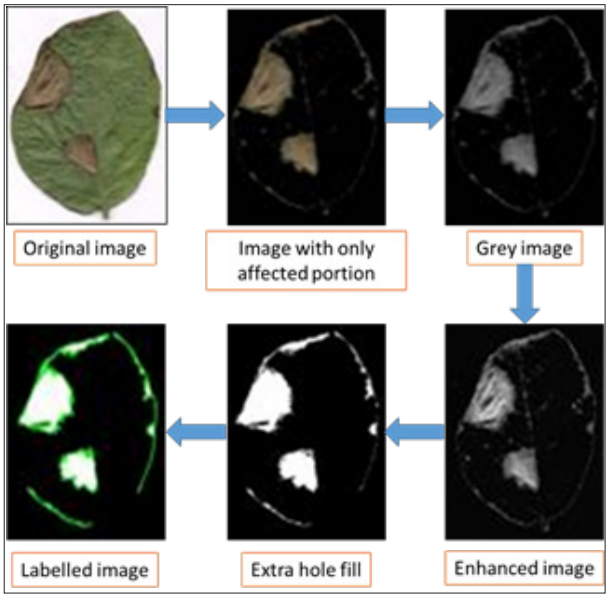

Figure 4: Segmentation of late blight affected area of leaflet.

Calculation of image-based scoring of late blight

Table 1: Henfling modified disease estimation scale for late blight of potato.

Grade	% Incidence	Nature of Infection (Level of Resistance / Susceptibility)
0	0	No disease
1	10%	Small lesions on the inoculated point with the lesion area less than 10% of the whole leaflet
3	10and 20%	Lesions area between 10% and 20% of the whole leaflet
5	20% and 30%	Lesion area between 20% and 30% of the whole leaflet
7	30% and 60%	Lesion area between 30% and 60%
9	Over 60%	Lesion area over 60% of the whole leaflet

The actual affected area on leaflets, leaves and plants have been calculated in percentages. The scores have been assigned based on Henfling modified disease estimation scale for late blight. The same pictures were provided to eight plant pathologists who are working at different posts associated with Plant Pathology for visual scoring. The 68 pictures were assigned score as 0,1,3,5,7 and 9 where 0 means no visual symptom expression and 9 means >60% leaf area infected, according to Henfling scale (Table 1) and the modal scale has been estimated. Percentage of matching has been calculated between image-based scoring system and eye estimation-based scoring system in each score and modal matching score. The average percentages of matching have been calculated from the matching scores. Correlation was performed using SPSS package version 23. The Henfling modified scale has been modified by changing the upper and lower limit of each score boundaries for increasing of matching percentage between image based and experts'-based scoring system.

Proposed image-based disease scoring scale for late blight of potato

The disease intensity of late blight of potato is estimated by plant pathologists based on their expertise. They have estimated scores based on Henfling modified disease estimation scale for late blight of potato. The resultant disease scores were varied among various subjects based on their experience. Moreover, image-based disease estimation system based on Henfling modified scale also varied from eye-based disease estimation score for late blight of potato. To bridge this gap, one modified scale for image-based scoring of late blight of potato has been proposed (Table 2).

Table 2: Modified image-based scoring scale for late blight of potato.

Grade	% Incidence	Nature of Infection (Level of Resistance / Susceptibility)
0	0	No disease
1	1.0 to 12%	Small lesions on the inoculated point with the lesion area less than 12% of the whole leaflet
3	12.1 to 16%	Lesions area between 12.1% and 16% of the whole leaflet
5	16.1 % and 35%	Lesion area between 16.1% and 35% of the whole leaflet
7	35.1% and 50%	Lesion area between 35.1% and 49%
9	Over 50%	Lesion area over 50% of the whole leaflet

Result and Discussion

After capturing, the late blight affected pictures have been selected for late blight disease estimation of potatoes based on various criteria of image processing. The affected portion has been segmented and affected pixels have been calculated. The percentages of affected area have been calculated based on total pixels in leaflet, leaves and potato plants and affected area on them is given in Table 3. The same pictures were also scored visually by Plant Pathologists' based on their experiences using Henfling modified scoring estimation scale for late blight of potato (Table 4) and the modal value of visual scoring has been estimated. The correlations among image based and visual disease scoring along with modal values have been calculated. The percentage of similarity between image-based scoring and pathologists-based scoring for each scoring have been calculated (Table 5). The overall matching score between image-based estimation and eye-based estimation was 69%. To increase the percentage of matching score, a new disease scoring scale for late blight of potato has been proposed in Table 2 and the percentages of matching has been calculated is 85% (Table 6). It was observed in the current experiment that the concurrent disease scores in the image based and eye estimated scoring system are differed significantly. Therefore, the percentage of matching between the two systems is not high (Table 5). However, the image-based disease estimation scores are constant in all times and it is not dependent on expertise of evaluators. In order to simulate the eye estimated expert scoring to layman, it is therefore necessary to modulate the existing Henfling modified scale to our need. The existing Henfling modified disease scoring scale is thus modified so that image-based disease estimation scoring for late blight of potato will work like Henfling modified scale.

Table 3: Image analysis-based assignment of disease scores to late blight infected potato leaves based on percentage of leaf area infected after Henfling (1979).

Sl. No.	Infected Image	Percentage of infection	Computational Scoring
1		15.85%	3
2		17.29%	3
3		14.21%	3
4		30.68%	7
5		11.81%	3
61		21.36%	5
62		15.06%	3
63		19.01%	3
64		21.06%	5
65		16.26%	3
66		22.25%	5
67		22.45%	5
68		22.39%	5

Table 4: Relationship between late blight disease scoring through visual scoring of subjects and image-based scoring system.

Sl. No.	Patholo-gist 1	Patholo-gist 2	Patholo-gist 3	Pathologist 4	Patholo-gist 5	Patholo-gist 6	Patholo-gist 7	Patholo-gist 8	Image based Scoring
1	5	5	1	1	3	3	3	3	3
2	3	3	1	1	3	3	3	3	3
3	3	3	1	3	3	3	3	3	3
4	9	9	3	7	5	7	9	5	7

5	3	3	1	1	1	3	1	1	3
61	5	5	3	5	7	7	7	5	5
62	3	3	3	3	5	3	5	3	3
63	7	7	3	5	7	3	7	5	3
64	3	3	5	3	5	5	5	3	5
65	5	7	7	5	7	7	5	3	3
66	5	5	5	5	7	7	7	3	5
67	5	3	5	3	5	7	7	3	5
68	5	3	5	3	5	5	7	3	5

Table 5: Relationship of Plant Pathologists' scoring with image-based scoring system following the scale of Henfling (1979).

Sl.No	Pathologist	Correlation with Image based Scoring	% of Matching					Average % Matching
			1	3	5	7	9	
1	1	0.77466	64.28	38.88	45.45	25	100	54.72
2	2	0.7713	78.57	36.11	18.18	25	100	51.57
3	3	0.7057	85.71	38.88	63.63	0	100	57.64
4	4	0.81567	85.71	47.22	54.54	75	100	72.49
5	5	0.73187	35.71	33.33	36.35	25	100	46.08
6	6	0.81332	78.57	61.11	36.36	50	100	65.2
7	7	0.75223	50	47.22	36.36	25	100	51.71
8	8	0.9	100	86	45.45	25	100	71.31
9	Modal value	0.84181	85.71	63.88	72.72	25	100	69.46

Table 6: Matching between image-based disease score scoring with eye estimation score using modified scale.

Different levels of disease severity grades	No. of samples having different disease grades based on observers (Plant Pathologists) records (Modal value)	No. of samples having different disease grades based on disease image system	No. of matching samples of different disease grades based on observers record and on image system analysis	Successful prediction of different disease grades based on image analysis system (in %)
1	14	15	13	86.66
3	26	23	20	86.95
5	15	25	13	52
7	7	1	1	100
9	6	4	4	100
Overall				85.12

Conclusion

In this research work, image-based disease estimation scoring for late blight of potato has been standardized to emulate the scoring according to Henfling (1979) by visual estimation in such a way that the image analysis-based scoring will generate tangible outcome towards visual estimation. It is observed that the matching scores based on proposed scale is given 85% accuracy which is a very good disease estimator. The disease scale is proposed based on the analysis of the captured images of leaflets, leaves and plants as a whole, affected by late blight, with white background. The uniform background of leaflets leaves, and plants have been made using white A4 paper below it. This modified scale will further need to be verified and standardized with larger set of images and with natural background in future. It may be emphasized from the above finding that this modified scale will be of great use to breeders, farmers and layman for late blight disease scoring in the absence of a qualified Plant Pathology expert or where there is no provision of the same. An inbuilt or cloud computation-based Android app developed using this app enriched with management aspects will generate valuable information to users for the identification of this disease, knowing the extent of infection and time and duration of management of this disease. This computational knowledge may further be extended for the identification of other foliar diseases of various crops including potato which could be a great support for the farming as well as scientific community [13-18].

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