Annals of Sri Lanka Department of Agriculture 2017. 19: 72 - 83

PRELIMINARY VALIDATION OF POTATO LATE BLIGHT FORECASTING MODELS TO PREDICT THE INITIAL OCCURRENCE OF DISEASE AND ITS MANAGEMENT BY FUNGICIDE SPRAYING

E.A.E.S.S. JAYASEKARA, K.P. SOMACHANDRA, K.K.N.N. GUNAWARDHANA, G.A.R. SOMASIRI AND W.M.S. GUNASEKARA

Regional Agriculture Research and Development Centre, Bandarawela, Sri Lanka

ABSTRACT

Late blight caused by *Phytophthora infestans* (Mont.) de Bary, can cause epidemics and significant yield losses on susceptible varieties under high relative humidity and low temperature conditions. Popular calendar based fungicide applications are not environmentally and economically viable. Predicting models which forecast initiation of late blight, coupled with scheduled subsequent fungicide applications aid to reduce initial inoculum level and the progress of disease development. Initial outbreak predicting models of Hyre's system (1954), moving average method (1998) and moving graph method (1978) were evaluated in fields at Regional Agriculture Research and Development Centre (RARDC), Bandarawela during 2014/2015 *Maha* and at RARDC- Bandarawela, Komarikagoda, Haputhalegama and Dehiwinna during 2016/2017 *Maha*. Calendar based fungicide applications were scheduled in 5, 7 and 14 days intervals with the onset of disease up to two months after seed potato planting. Daily meteorological data, date of symptom initiation and weekly disease severity data were recorded. The initiation of late blight was predicted accurately by Hyre'system at RARDC- Bandarawela and Dehiwinna and by moving average method at Komarikagoda and Dehiwinna. There were no significant differences among scheduled fungicide applications for late blight severity and yield during 2016/2017 *Maha* season.

Key words: Late blight, forecasting, fungicide application, models

INTRODUCTION

Late Blight of potato caused by *Phytophthora infestans* (Mont.) De Bary is one of the most destructive diseases worldwide. It can cause 40-70 % yield loss (Sengooba *et al.*, 1999) depending on the varietal susceptibility and environmental conditions. Environment plays a main role in development of the epiphytotics. The optimum temperature for development of *P. Infestans* is 16-24 ^{0}C (Zargarzadeh *et al.,* 2008). Sporangia are produced between 8.5-26 ^{0}C temperature and 90-100 % Relative Humidity (RH) whereas oospores produced between 8–22 ^{0}C with an incubation period of 7-14 days. Also prolonged survival of sporangia requires high RH and a film of water and the detachment of sporangia occurs due to changes in humidity (Arora *et al.,* 2014). Management of this serious disease is a challenge in both field and storage with limited access to resistant varieties (Henderson *et al*., 2007). Although, current management is calendar based frequent application of fungicides, it is not economically benefited and environmentally friendly (Ahmed *et al.,* 2016). Reduction of initial inoculum and slowdown of the disease development were the key points for effective management of late blight in temperate conditions (Singh *et al*., 2013).

Forecasting has been widely used for predicting disease outbreaks, spray scheduling and reducing cost and environmental hazards. Forecasting models predict the outbreaks or changes in intensity of a disease on the basis of information of weather, crop and pathogen or combinations of them. Numerous Potato Late Blight (PLB) forecasting models have been developed and used in many countries. But occurrence and spreading of PLB vary with the growing season and location (Zargarzadeh *et al*., 2008). Since there were no studies carried out on PLB forecasting in Sri Lanka, identification of the applicability of extensively evaluated models in predicting PLB in potato growing areas will reduce the excessive use of fungicides. However, studying of fungicide application with predicting models during disease development is difficult task with limited access to hourly weather data. Therefore, identification of predicting model for disease initiation and best calendar based fungicide program for subsequent applications will be appropriate for minimizing excess use of fungicides. The objective of this study was to validate the selected PLB forecasting models and to evaluate pre-scheduled fungicidal sprays.

MATERIALS AND METHODS

Hyre's (1954) system (Singh *et al*., 2013), moving average method (Hoon *et al.,* 1998) and moving graph method (Hahm *et al.,* 1978) to predict the initial occurrence of potato late blight were evaluated in this study. These models were selected based on model required conditions remained in selected locations and availability of facilities for recording weather parameters. Hyre's system forecasts the initiation of late blight symptoms in 7-14 days after 10 consecutive

Blight Favourable Days (BFD) of 5-days average temperature is below 25.5 ^{0}C and the total rainfall for the last 10-day period is ≥ 30 mm. Also days with minimum temperature below 7.2 ^{0}C are considered unfavourable (Singh *et al*., 2013). Moving Average Method (MAM) predicts the initial occurrence of PLB in 7-14 days after 7 consecutive BFD of above 79 % of 5-day average RH and above 12 ^{0}C of 7-day moving average air temperature (Hoon *et al.*, 1998). Moving graph method (MGM) forecasts the first outbreak of PLB in 7 days after daily average RH ≥ 85%, 7 days accumulated rainfall ≥ 30 mm and 7 days average temperature ≥ 12 ^{0}C together (Hahm *et al*., 1978 and Min, 2014).

Studies were conducted at RARDC, Bandarawela (6^0 49' 13.66" N, 80^0 58' 35.41" E) during 2014/2015 *Maha* season and at RARDC- Bandarawela, Komarikagoda (6^0 49' 28.85" N, 80^0 58' 36.60" E), Haputhalegama (6^0 47' 37.31" N, 80^0 57' 14.33" E) and Dehiwinna (6^0 53' 30.01" N, 80^0 58' 40.27" E) during 2016/2017 *Maha* season. Well sprouted Granola seed potatoes were planted in 296th day of year 2014 at RARDC- Bandarawela and 355th day of year 2016 at Haputhalegama, 4th day at Komarikagoda, 33rd day at RARDC- Bandarawela and 67th day at Dehiwinna during year 2017. Agronomic practices, except application of fungicides, in all locations were done according to Department of Agriculture (DOA) recommendations. Commercially available mixed fertilizers were applied in Dehiwinna instead of DOA recommendation. Late blight predictions for selected locations were based on meteorological data recorded at RARDC, Bandarawela. The data were daily rainfall (mm), minimum and maximum temperatures (^{0}C) and relative humidity. Air distance between meteorological station to Haputhalegama, Komarikagoda and Dehiwinna were 3.92 km, 0.69 km and 7.07 km respectively. Late blight infection was done under natural infection. First PLB symptoms observed date and model conditions satisfied durations from seed potato planting were recorded and assessed the visual late blight symptoms observed date coincidence on model predicted late blight occurred durations. Also number of fungicides applied by farmers before model conditions satisfied was recorded during 2016/2017 *Maha*.

Evaluation of scheduled fungicide applications was done at RARDC-Bandarawela, Haputhalegama and Komarikagoda in 2016/2017 *Maha* season. Application of fungicides was scheduled in 5, 7 and 14 days intervals. Spraying intervals were selected based on Krause's Blitecast system predicted spray schedules (Bootsma, 1979). Treatments were T1- fungicide application in 5 days interval, T2- fungicide application in 7 days interval, T3-fungicide application in 14 days interval and T4- untreated control. Experiments were laid out in a randomized complete block design with four replicates. Fungicide spraying was initiated with the onset of disease up to two months after seed potato planting. Fungicides and their application intervals were based on DOA recommendations. First spraying was Mancozeb 64% + metalaxyl 8 % WP in all treatments except T4. Then, Mancozeb 80% WP in 5 days interval followed by Mancozeb 64% + metalaxyl 8% WP in 15 days interval in T1 whereas Mancozeb 80% WP in 7 days interval followed by Mancozeb 64% + metalaxyl 8 % WP in 14 days interval in T2. Mancozeb 64% + metalaxyl 8% WP was sprayed in 14 days interval in T3 (Table 1). Disease severity values were obtained using 1-9 diagrammatic scale representing damage percentage of total plant (1: $\leq$ 10 %, 2: 11-25 %, 3: 26-40 %, 4: 41-60 %, 5: 61-70 %, 6: 71-80 %, 7: 81-90 % and 8: $>$ 90 %), in weekly intervals with the onset of disease. Disease severities were converted to measurements of Area Under Disease Progress Curve (AUDPC) (Jesus Junior *et al*., 2001).

Table 1. Number of fungicides applications in 2016/2017 *Maha* season.

Treatments	Haputhalegama		Komarikagoda		RARDC-Bandarawela	
	Mancozeb 64%+metalaxyl 8% WP	**Mancozeb 80% WP**	**Mancozeb 64%+metalaxyl 8% WP**	**Mancozeb 80% WP**	**Mancozeb 64%+metalaxyl 8% WP**	**Mancozeb 80% WP**
T1	2	4	2	4	2	2
T2	2	3	2	3	2	2
T3	2	-	2	-	2	-
T4	-	-	-	-		

Recorded data were subjected to statistical analysis using ANOVA of SAS statistical data analysis software. Duncan's multiple range tests was used to determine the significant differences among treatment (Sahu *et al.,* 2013).

RESULTS AND DISCUSSION

Mean daily temperature was around 20.2 ^{0}C and 19.6 ^{0}C in 2014/2015 *Maha* and 2016/2017 *Maha* seasons from November to March, with a daily minimum temperature around 16.2 ^{0}C and 14.5 ^{0}C, respectively. Relative humidity above 79 % was 47 % of days in 2014/2015 *Maha* whereas 39 % in 2016/2017 *Maha* from November to March. Rainfall from November to March was recorded on 55 % of days in 2014/2015 *Maha* and 35 % in 2016/2017 *Maha*. Several authors reported on the conducive weather conditions for the development of late blight. Similar conditions were experienced at all locations throughout the study period. Olanya *et al*., (2007) reported that temperature, RH and leaf wetness apparently influence on various stages of the PLB pathogen cycle and disease development. Incidence of PLB in the Columbia Basin significantly increased with reduction of solar radiation and increase of number of rainy days (Johnson *et al*., 2009). In the present study also number of rainy days was higher and created conducive conditions for late blight development. Results revealed that Hyre's system and MAM anticipated the initial occurrence of PLB accurately in 2014/2015 *Maha (*Figure 1 and 2).

MAM accurately predicted the initiation of late blight in Komarikagoda while both Hyre and MAM predicted the initiation at RARDC- Bandarawela and Dehiwinna, in 2016/2017 *Maha* season(Figures 4 and 5). Initial infections observed mostly on top most leaves of the canopy in both seasons, suggesting a predominance of air borne inoculum. Some plots showed initial lesions after 1-2 weeks of initial symptoms in other plots due to natural inoculation. Hyre's system blight favourable conditions prevailed during 296-312 days and its predictions duration was 312-319 whereas MAM conditions prevailed during 302-308 days and its predictions duration was 315-322 in 2014/2015 *Maha.* Also Hyre's system conditions remained during 51-60 days and 67-79 days and their prediction durations were 67-74 days and 84-91 days at RARDC, Bandarawela and Dehiwinna, respectively. MAM conditions persisted during 22-28 days and 69-76 days their prediction durations were 35-42 days 82-89 days at Komarikagoda and Dehiwinna respectively. Hyre's system was the simplest model among available models but has been extensively evaluated and implemented by growers in the North Eastern United States (Singh *et al.,* 2013). However, scientists observed that late blight occurrence was took place in$\leq$ 25^{0}C in Venezuela and, modified the model as 5 day average temperature $\leq$ 22^{0}C (Garcia *et al.,* 2008). MAM accurately predict the date of initial development of PLB with the 92.3% accuracy in Korea (Hoon *et al.,* 1998).

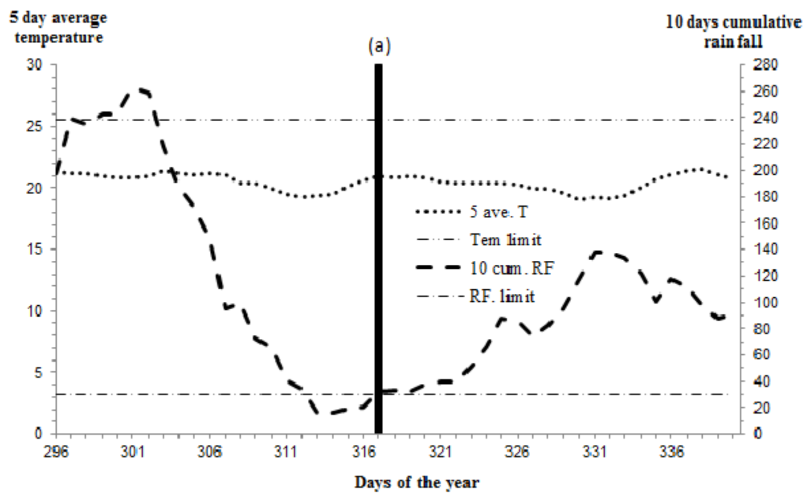

Figure 1. Five day average temperature, ^{0}C (5 avg. T), Ten days cumulative rainfall, mm (10 cum. RF), Temperature$\leq$ 25.5 ^{0}C (Tem. Limit), Rainfall $\geq$ 30mm (RF limit), (a) Day of initial PLB symptoms observed during 2014/2015 *Maha* at RARDC, Bandarawela

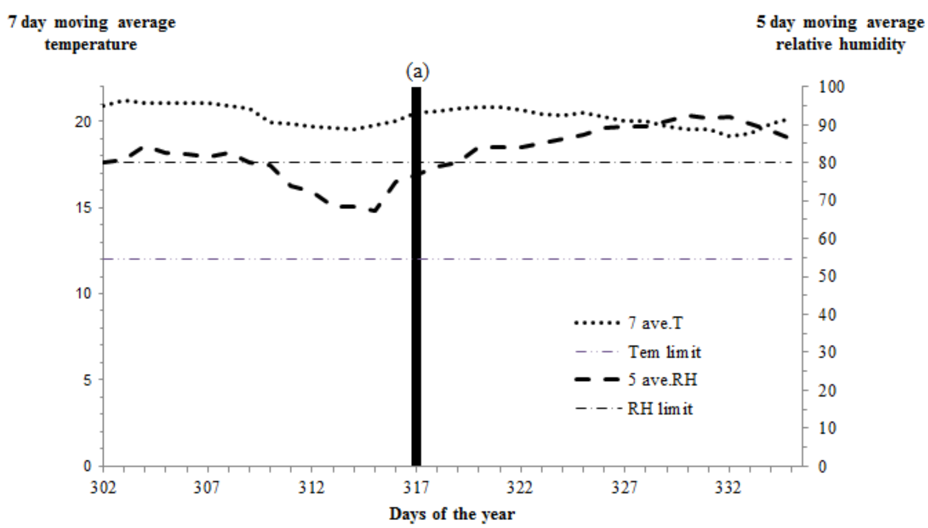

Figure 2. Seven day moving average temperature ^{0}C (7 avg. T), Five day moving average relative humidity (5 avg. RH), (a) Day of initial PLB symptoms observed during 2014/2015 *Maha* at RARDC, Bandarawela

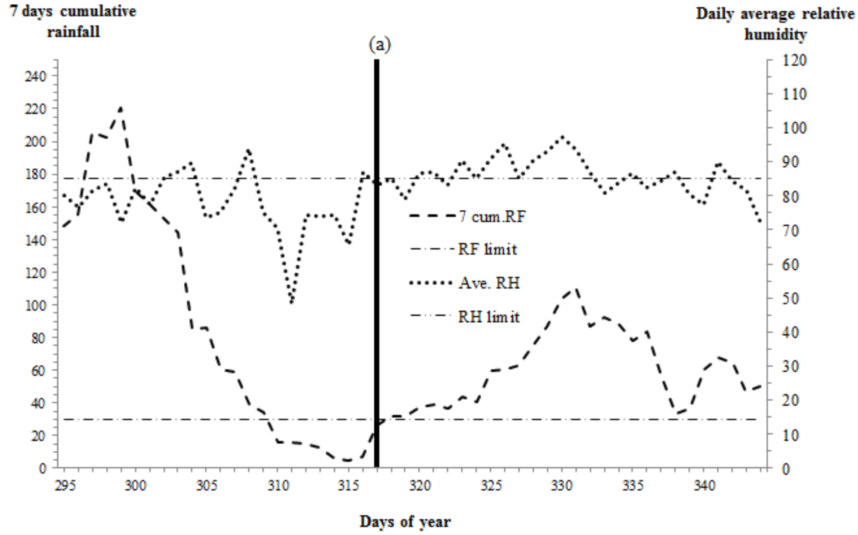

Figure 3. Seven days cumulative rainfall, mm (7 cum. RF), Daily average relative humidity (Avg. RH), (a) Day of initial potato late blight symptoms observed during 2014/2015 *Maha* at RARDC, Bandarawela.

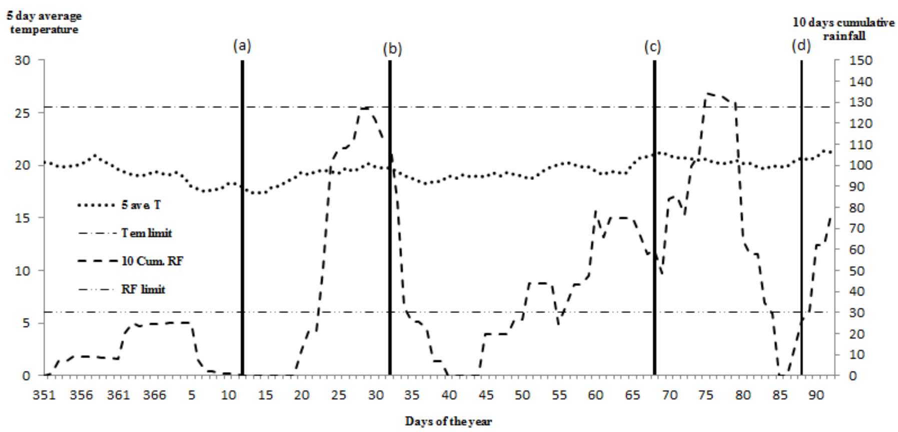

Figure 4. Five day average temperature, ^{0}C (5 avg. T), Ten days total rainfall, mm (10 Cum. RF), Temperature ≤ 25.5 ^{0}C (Tem. Limit), Rainfall ≥ 30mm (RF limit), (a),(b), (c), (d) - Day of initial PLB symptoms observed at Haputhalegama, Komarikagoda, RARDC-Bandarawela, Dehiwinna respectively during 2016/2017 *Maha.*

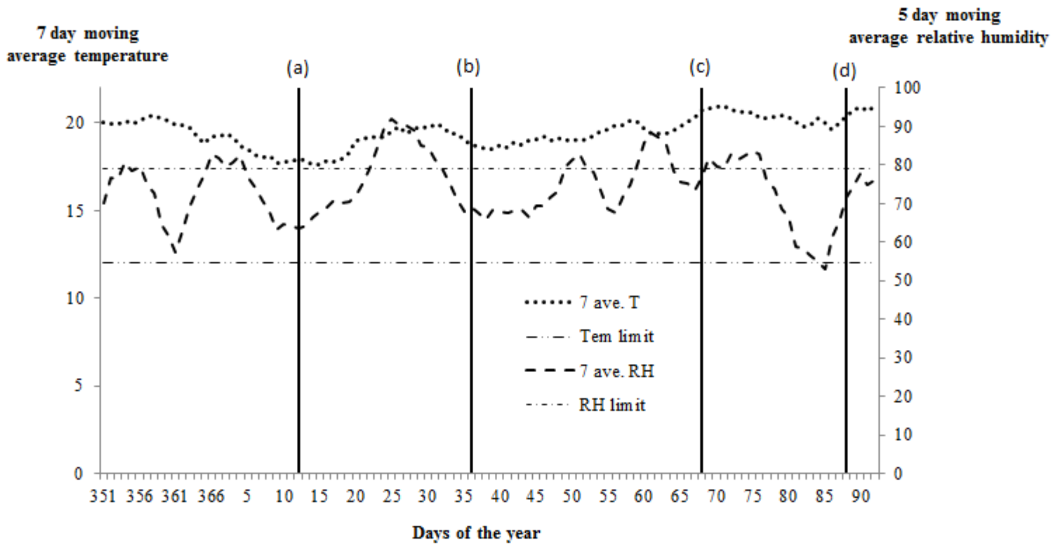

Figure 5. Seven day moving average temperature ^{0}C (7 avg. T), Five day moving average relative humidity (5 avg. RH), (a), (b), (c), (d) - Day of initial PLB symptoms observed at Haputhalegama, Komarikagoda, RARDC-Bandarawela, Dehiwinna respectively during 2016/2017 *Maha.*

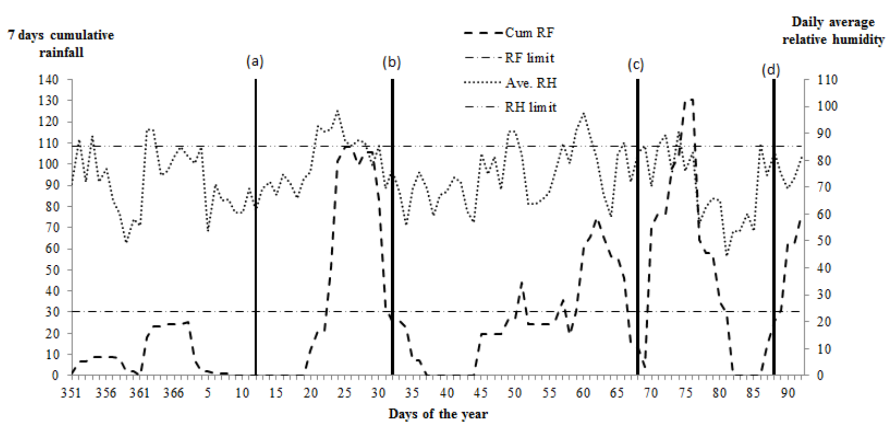

Figure 6. Seven days cumulative rainfall, mm (7 Cum. RF), Daily average relative humidity (Avg. RH), (a), (b), (c), (d) - Day of initial PLB symptoms observed at Haputhalegama, Komarikagoda, RARDC-Bandarawela, Dehiwinna respectively during 2016/2017 *Maha.*

Ahmed *et al*. (2015) illustrated that maximum and minimum temperatures, RH, rainfall and wind speed in the range of 16-20 ^{0}C, 1-6 ^{0}C, 63-71 %, 1.5-3.75 mm and 1-5.5 km/h respectively were conducive for PLB in Pakistan. Zargarzadeh *et al*. (2008) concluded that about 30 mm rainfall and > 19 ^{0}C during the critical period of 10 days of growing season were favouring the development of PLB in Ardabil plain of Iran.

Johnson *et al*. (1996) described that many weather based forecasting models assume that initial inoculum is constantly present and it is important for development of late blight epidemics. Low level of initial inoculum, high quality seeds and good sanitation practices are important requirement for the successful operation of forecast models. Ryu *et al.* (2005) found tuber yields were reduced to 42-63 % and it was closely related with the time of first occurrence of the disease in organic farming fields. Hours of combined occurrence of favourable temperature (10 ^{0}C–27 ^{0}C) and humidity (≥ 80 %) were significant predictors of disease occurrence (Henderson *et al*., 2007).

Initial symptoms of PLB were not observed 7 days after satisfying conditions of MGM in both seasons (Figure. 3 and 6). MGM based on 7- day mean temperature and 7- day cumulative rainfall failed for predicting occurrence of late blight of the Daekwanryeong area in Korea but addition of data of minimum temperature above 10 ^{0}C and average humidity above 85 %, MGM accurately predicted initial occurrence of late blight (Hahm *et al*., 1978). Moving sum of 7 days relative humidity ≥ 85% for at least 90 hours coupled with 7 day moving sum of temperature between 7.2 to 26.6 ^{0}C for at least 115 hours could forecast onset of late blight within 10 days in Punjab (Arora *et al.,* 2012).

Any tested models could not predicted first occurrence of late blight in Haputhalegama. 10 days cumulative rainfall lied 1-25 mm from seed planting to disease development whereas 5-consecutive BFD of MAM was remained before occurrence of late blight in Haputhalegama. But, prevailed weather conditions were too closer for MAM conditions. Although, Haputhalegama located 3.92 km away from RARDC- Bandarawela, microclimatic conditions of the experimental site might be in favour for late blight development.

Effect of scheduled fungicide applications on disease severity of PLB and yield

Results indicated that fungicide treated plots had significantly low late blight pressure compared to untreated plots in all locations (Table 2). There were no significant differences among fungicide treated plots in terms of disease severity during 2016/2017 *Maha* season. Yield was significantly low in untreated plots compared to treated plots and no statistical differences among fungicide treated plots for yields in trials located at Komarikagoda and RARDC-Bandarawela. Conversely, there were no significant differences among all treatments at Haputhalegama for yield. Farmers applied Mancozeb 80% WP at two instances at Komarikagoda and one time at Dehiwinna before any model conditions start to appear.

Table 2. AUDPC values and yield (tons/ha) in 2016/2017 *Maha*.

Treatments	**Haputhalegama**		**Komarikagoda**		**RARDC-Bandarawela**	
	AUDPC values	**Yield (tons/ha)**	**AUDPC values**	**Yield (tons/ha)**	**AUDPC values**	**Yield (tons/ha)**
T1- 5 days interval	21.18 [b]	33.49 [a b]	24.43 [b]	29.86 [a]	46.74[c]	16.76 [a]
T2- 7 days interval	21.90 [b]	31.78 [a b]	25.74 [b]	25.17 [a]	50.54[c b]	17.08 [a]
T3 – 14 days interval	22.90 [b]	27.23 [b]	27.92 [b]	26.61 [a]	55.69 [b]	14.17 [a]
T4 – Untreated control	33.80 [a]	25.55 [c]	41.40 [a]	12.71 [b]	63.88 [a]	8.68 [b]
CV %	10.48	10.14	10.51	18.45	7.81	21.73

Note: Means followed by the same letter in each column are statistically similar to each other at 5% level of probability

Subhani *et al.* (2015) found that maximum protection from late blight was observed at 7 and 14 days spray intervals while least protection was observed 21 and 28 day spray intervals in Pakistan. The highest benefit was achieved by applying Ridomil (Mancozeb 64%+Metalaxyl 4% WP) once and Mancozeb 80% subsequently at 14 and 21 days intervals in southwestern Uganda (Kankwatsa *et al.,* 2003).

CONCLUSIONS

First occurrence of PLB was accurately predicted by Moving Average Method at Komarikagoda and Dehiwinna while prediction by Hyre's system at RARDC – Bandarawela was more towards the reality . Further validation of these models in different locations will be essential before before being used other potato growing areas.

REFERENCES

Ahmed, N., M.A. Khan, N.A. Khan, and M.A. Ali. 2015. Prediction of potato late blight disease based upon environmental factors in Faisalabad, Pakistan. Journal plant pathology and microbiology. S3: 008. doi:10.4172/2157-7471.S3-008.

Ahmed, N., M.A. Khan, N.A. Khan, and M.A. Ali, 2016. Development of predictive model based on epidemiological factors for the management of potato late blight disease. International Journal of Agriculture and biology. 18: 362–369.

Arora, R.K., I. Ahmed and B.P. Singh. 2012. Forecasting late blight of potato in Punjab using JUSLACAST model. Potato Journal. 39: 173-76.

Arora, R.K., S. Sharma and B.P. Singh. 2014. Late blight disease of potato and its management. Potato Journal. 41(1): 16-40.

Bootsma, A. 1979. Potato late blight forecasting in Prince Edward island in 1978. Canadian plant disease survey. 59:3. 63-66.

Garcia, B. I. L., P. C.Sentelhas, L. R. Tapia and G. Sparovek. 2008. Climatic risk for potato late blight in the Andes region of Venezuela. Scientia Agricola. 65: 32-39.

Hahm, Y.I., B.H. Hahn, and J.D. Franckowiak. 1978. Forecasting late blight of potatoes at the Alpine area in Korea. Korean journal plant protection. 17 (2): 81-87.

Henderson, D., C. J. Williams and J. S. Miller. 2007. Forecasting late blight in potato crops of southern Idaho using logistic regression analysis. Plant Disease. 91: 951-956.

Hoon, A.J., Y.I. Hahm and E.W. Park, 1998. Development of 'moving average method' for prediction of initial appearance of potato late blight. Korean Journal Plant pathology. 14(1): 34-40. Abstract retrieved from Agris Food and Agriculture Organization of the United Nations.

Jesus Junior,W.C., F.X.R. Vale, C.A. Martinez, R.R. Coelho, B. Hau, L. Zambolim, L.C. Costa, and A.B. Filho, 2001.Effects of angular leaf spot and rust on yield loss of *Phaseolus vulgaris*. Epidemiology. 91(11): 1045-1053.

Johnson, D.A., J.R. Alldredge and D.L. Vakoch. 1996. Potato late blight forecasting models for the semiarid environment of south-central Washington. Phytopathology. 86: 103-106.

Johnson, D.A., T.F. Cummings, R.A. Ghanem, and J.R. Alldredge. 2009. Association of solar irradiance and days of precipitation with incidence of potato late blight in semiarid environment of the Columbia basin. Plant disease. 93(3): 272-280.

Kankwatsa, P., J. Hakiza, M. Olanya and E. Adipala. 2003. Efficacy of different fungicides spray schedules for control of potato late blight in southwestern Uganda. https://www.researchgate.net/publication/248416331_Efficacy_of_different_fungicide_spray_schedules_for_control_of_potato_late_blight_in_Southwestern_Uganda. (Accessed on 02.04.2017)

Min, K. 2014. Potato pests and management. 2014 KOPIA group training on seed potato production. pp 137.

Olanya, O.M., G.C. Starr, C.W. Honeycutta, T.S. Griffin and D.H. Lambert. 2007. Microclimate and potential for late blight development in irrigated potato. Crop Protection. 26: 1412–1421.

Ryu, K., H. Jee, D. Choi, J. Cheon, J. Kim, and B. Kim. 2005. Disease progress and yield loss of potato late blight caused by *Phytophthora infestans* in organic farming fields. Research in plant disease. 11(2): 122-127.

Sahu, D.K., C.P. Khare, H.K. Singh and M.P. Thakur. 2013. Evaluation of newer fungicide for management of early blight of tomato in Chhattisgarh. The bioscan. 8(4): 1255-1259.

Sengooba, T. and J. J. Hakiza. 1999. The current status of late blight caused by *Phytophthora infestans* in Africa, with emphasis on eastern and southern Africa. Late Blight a Threat to Global Food Initiative on Late Blight Conference. pp 25-28.

Singh, V.K., Shailbala and V.S. Pundhir. 2013. Forecasting models for potato late blight management-A review. Agricultural Reviews. 34(2): 87-96.

Subhani, M.N., T.S. Sahi, A. Rehman, W. Wakil. 2015. Efficacy of fungicides by *Phytophthora infestans* (Mont.) de Bary. Acedemic research journal of agricultural science and research. 3:9.245-250.

Zargarzadeh, F.G., A. Ghorbani, A. Asghari, and G. Nouri-Ganbalani. 2008. Journal of Food, Agriculture and Environment. 6(3&4): 200-205.