Review Article

Predicting the major organism species in tobacco in Cao Bang province, Vietnam based on the weather conditions

ABSTRACT

In recent years, some organism species are appearing popularly in the tobacco in Cao Bang province, Vietnam, and caused severe damage to the tobacco yield and quality such as budworm (*Helicoverpa assulta* Guene), aphid (*Myzus persicea* Sulzer), and powdery mildew (*Erysiphe cichoracearum* D.C). To manage them effectively, forecasting and controlling insect pests play an important role in tobacco cultivation. The predictive model was built base on the Skybit, Fuzzy, and Degree-days model to forecast and give suitalbe control methods for major insect pests in tobacco. This model is run on Exel software and calculated by an IF function for the growth of the organism. Result of the model predicted accurately the tobacco budworm, aphids, and powdery mildew damaging tobacco in Cao Bang in April 2022. Based on the results of prediction, we give proper control methods for each insect pests, preventing the quick growth and development of the organism species in the field, reducing the use of pesticides, and increasing the income of the growers. This model has also applied to forecast other pests in the tobacco in Vietnam. To increase the quality of the prediction, the model will continue to be perfected and completed in the coming years based on the practice field.

Keywords: Tobacco budworm, aphid, Powdery mildew, and forecast model.

1. INTRODUCTION

Flue-cured tobacco (*Nicotiana tabacum* L.) is a major crop in Cao Bang province, Vietnam during the growing season from December 2021 to May 2022. Some major organism species in the tobacco plants include the tobacco budworm (*Helicoverpa assulta* Guene), tobacco aphid (*Myzus persicea* Sulzer), and powdery mildew (*Erysiphe cichoracearum* D.C). The occurrence of insect pests is one of the main reasons for yield loss. The appearance, development, and spread of organism species mainly depend on the weather, sensitive crop, infective resources, and cultivating conditions. In that, the insects are the most susceptible group, so thermal changes have a direct effect on their growth, reproduction, and existence (Bale JSB et al., 2002, Somala Karthik et al., 2021). When lack one of those, the diseases and insects can not develop (Nguyen Van Chin, 2021).

Insects develop rapidly in warm weather, and population can build up quickly in situations where natural enemies are destroyed and the weather is favourable. The abiotic factors (meteorological parameters) affect the pest abundance and their distribution. Temperature is the most crucial abiotic factor influencing the rate of growth and development of insects. However, relative humidity (RH) and temperature are the chief weather parameters that largely direct the activity of a given species of insect. The interaction between pest activity and abiotic factors helps to give predictive models and control methods (M. M. H. Khan, 2019). Heavy and prolonged periods of rain result in the death of *H. armigera* (Ge, F et al., 2003). It also increases air humidity and soil water content that increases the deadly rate of pupae (Chen et al., 2003), and decreases capable flight action, copulation, and fecundity of butterflies. The flight action of adult *H. armigera* depends on relative humidity. When RH of 60% - 90% is helpful for flight action of adult *H. armigera* (Wu & Guo, 1996; Li et al., 2016). In addition, the flight of *H. armigera* is related to temperature (Wardhaugh et al., 1980), It is the most favourable temperatures for its flight range from 20°C to 22°C (Gao & Zhai, 2010) or 20°C to 24°C (Wu & Guo, 1996) lead to increase the flight distance of moths and population spreading. The temperature and humidity affect the parasitization rates of *H. armigera* which affects their population.

Fungal diseases, the appearance, development, and spread of them mainly depend on the weather, sensitive crops, and infective resources in the field (relation between host, pathogen, and environment). When lacks one of those, the disease can not develop. Fungal diseases can only occur, develop and cause strong harm when the favourite weather conditions such as temperature, humidity or wet leaf (Rabiu Olatinwo et al., 2014). In that, leaf wetness (LW) plays an important role in the growth, development, and damaging capability of fungal disease (Nguyen Van Chin, 2021). Because spores of fungi can only germinate and infect into leaf when the surfaced leaf has continuous leaf wetness for many hours or days, with favourite temperature in a period of LW appearance. Leaf wetness is the presence of free water on the surface of a crop canopy. It results primarily from three sources: water that had been intercepted by the canopy during a rainfall or fog event; overhead irrigation; or dew, which could form on the leaf surface of the crop canopy, mainly on the bottom leaves (Tracy Rowlandson et al., 2015). Leaf wetness has a relative humidity and disease only appeared when RH is over 90%; or ≥ 85% if the field is planted with a high density, the leaves canopy each other; and RH ≤ 70%, it is dry periods and leaf wetness can not occur on the leaf surface (WILKS D.S et al., 1991, Sentelhas P. C et al., 2008, A. Ghobakhlou et al., 2015, K. S. Kim et al., 2002, Gleason, Mark. L et al., 2001); leaf wetness only appears when RH ≥ 95% (Tracy Rowlandson et al., 2015).

Skybit model was developed by Joe Russo in 1993 as a joint venture between ZedX, Inc and Meso, Inc. It uses weather data from U.S. National Weather Service's National Centres for Environmental Prediction (NCEP) to plant disease and insect forecasting for many crops in the world such as apple, carrot, grape, peanut, potato, tomato, wheat (Matthew Wallhead et al., 2017). Predicting by degree days: Insects are cold-blooded animals and the temperature plays a major role in their growth and development. Each insect has a temperature threshold for its growth and development such as min temperature level ($TL_{min)}$, max temperature level ($TL_{max)}$, and optimum temperature level ($TL_{opt)}$. No development occurs when temperatures are below TLmin or above Tlmax (termed upper cutoff). Insects have an optimum temperature range in which they will grow rapidly. These values are used to predict insect activity and the appearance of symptoms during the growing season (Ric Bessin et al., 2019). The fuzzy logic model is used in many applications like data mining, control applications, and decision support system. Fuzzy is applied to forecast insect pests in agriculture based on the weather. The activity of diseases and insects only happens in a specific range of a proper temperature and humidity level (Vidita Tilva et al., 2013).

The Vietnam National Tobacco Institute has been applying a pests forecast model based on the weather, and climate that is built based on the Skybit, Fuzzy, and Degree-days models, and is run on Excel software in recent years. The resulting forecast of the model helped us give the best control methods to prevent the growth heavily of organism species, reduce the use of pesticides, and increase the farmer's income. To increase quality forcast and control, this pests forecast model will continue to be studied, performed, and completed in next years in the field condition.

2. MATERIALS AND METHODS

Forecast area: The tobacco growing area of Cao Bang province, Vietnam.

Forecast objects: Budworm (*Helicoverpa assulta* Guene), Aphid (*Myzus persicea* Sulzer), and Powdery mildew (*Erysiphe cichoracearum* D.C).

Forecast time and the growing stage of tobacco: We predict the insect pests in April 2022 when tobacco is strongly growing and developing stage. At stage is easy to infect many important organism species such as budworm, aphid, and powdery mildew.

Weather data for the forecast: The 15 days-weather forecast data of Cao Bang is synthesized from websites such as myweather2.com, tutiempo.net, and myforecast.com.

Forecast methods: Our predictive model is built based on the Skybit, Fuzzy, and GDD models and is run on Excel software. The model assesses how favourable weather conditions are for each organism species and how severe each disease may be. The growth of the organism is calculated by an IF function in Excel. In addition, based on the current surveying, history field, varieties, stage growth of crops, the experience of the predicter, biologies of insect pests to decide a final predict result and give some good controls. Some damage levels of organism species such as: 1) Insect: 0: No active; 1: Active and very light damage; 2: Active and light damage; 3: Active and moderate; 4: Strong action and severe damage; 2) Disease: 0: No active; 1: Active and no damage; 2: Active and light damage; 3: Active and moderate damage; 4: Strong action and severe damage.

Chart 1: Some disease and weather information

Disease and insect information	
AW	Accumulated Wetness hours for a continuous wetness event. In the case of multiple events in a day, this value represents the most severe event of Pests.
TW	Average Temperatures during those wet hours
TL	Temperature levels for infection and growth of insects and diseases: TLmin, TLmax, and TLopt.
GDD	Grow degree day of insects
ADD	Accumulated degree-days of insects
RH	Relative humidity for infection and growth of pests
PW	Daily Disease/insect Severity rating ranging from 0 (No damage) to 4 (severe)

Weather information	
T_{max}	Daily Maximum Temperature.
T_{min}	Daily Minimum Temperature.
T_{av}	Daily average temperature
Prec	Daily Precipitation
ARH	Daily Average Relative Humidity.
Weather	Cloud, overcast, rainy, sunny, wind
LW	The total number of Leaf Wetness hours for the day.

Chart 2: Rules to estimate insect/disease in predict following formula:

IF function: IF (Humidity is dry) and (Temperature is very low) and (Leaf wetness duration is short) and (Average Temperatures during those wet hours is very low) and (compared to growth conditions of pests) then (Disease/insect is No active);

- IF function: IF (Humidity is dry) and (Temperature is low) and (Leaf wetness duration is short) and (Average Temperatures during those wet hours is low) and (compared to growth conditions of pests) then (Disease/insect is No active);

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- IF function: IF (Humidity is high) and (Temperature is optimal) and (Leaf wetness duration is long over Leaf wetness hours that optimal growth of disease) and (Average Temperatures during those wet hours is optimal) and (compared to growth conditions of pests) then (Disease is very strong action and cause severe to very severe damage/insect is low action);
- IF function: IF (Humidity is a medium level) and (Temperature is optimum) and (Leaf wetness duration is very short or no leaf wetness) and (compared to growth conditions of insect pests) then (Disease is No active/insect is very strong action and can cause severe damage).

3. RESULTS AND DISCUSSION

3.1. Forecast the tobacco budworm and aphid on the tobacco plants in Vietnam

3.1.1. Biological information about the tobacco budworm and aphid

Data in table 1 showed that the budworm can only appear, develop, and harm when the temperature increases in the range of 13.3 - 33°C and humidity: 50 - 90%. The optimum temperature and RH for active insects are from 21 - 24°C and 80 - 85%, respectively. When the temperature is lower than 13.3°C and above 33°C, insects are not active. Those optimum elements are the same study results of Wu & Guo, 1996; Li, Zheng & Tang, 2016; Gao & Zhai, 2010. For aphids, their temperature level increases in the range of 4.9 - 32°C and humidity: 60 - 100%, the optimum temperature and RH range from 20 - 25°C and 80 - 85%, respectively. When the temperature is lower than 4.9°C and above 32°C, aphids are not active.

Table 1. The growing conditions of the tobacco budworm and aphid

Insect information	Forecast levels				
	0	1	2	3	4
Tobacco budworm					
The gowing temperature level of egg, adult and fertility (°C)	< 13,3 ≥ 33	13,3 - < 18 > 30 - < 33	18 - < 21 > 27 - ≤ 30	21 - 27	21 - 27
The gowing temperature level of larvae (°C)	< 13,3	13,3 - < 18 > 30 - < 33	18- <2 2 >24 -< 30	22 - 24	22 - 24
Relative humidity (RH) %	50	60	>60 - < 75 > 90 - 100	75- < 80 > 85 - ≤ 90	80 - 85
[1]AGDD (egg – adult): 413.3°C, Base development temperature: 13.3°C, Upper development temperature: 33°C					
Tobacco aphids					
The gowing temperature level (°C)	< 4.9; ≥ 32	4.9- < 17 > 30 - < 32	17 - < 20 > 25 - ≤ 30	20 - 25	20 - 25
Relative humidity (%)	60	70	70 - < 80 > 95 - 100	85 - 95	80 - 85
[2]AGDD (1instar – adult): 130°C, Base development temperature: 4.9°C, Upper development temperature: 32°C					

Note: [1]AGDD= Butler et al., 1976, [2]AGDD= Whalon, M. E., and Z. Smilowitz.

Table 2. Predict the budworm and aphid damaging the tobacco in Cao Bang in April 2022

Date	Weather, climate conditions					Tobacco budworm								Tobacco aphid						
	T_{max}	T_{min}	T_{av}	RH	Pre mm	DD	ADD	Ge	P^T A,E,P	P^T La	P^{RH}	P	O %	DD	ADD	Ge	P^T	P^{RH}	P	O %
401	18	14	16.0	68	4	2.7	3	1	1	1	2	1	≤1	11.1	11	1	1	1	1	≤1
402	18	12	15.0	66	1	1.8	5	1	1	1	2	1	≤1	10.1	21	1	1	1	1	≤1
403	24	10	17.0	48	0	4.1	9	1	1	1	0	1	≤1	12.1	33	1	1	0	1	≤1
404	24	9	16.5	52	0	3.8	12	1	1	1	1	1	≤1	11.6	45	1	1	0	1	≤1
405	26	12	19.0	55	0	5.8	18	1	2	2	1	1	≤1	14.1	59	1	2	0	1	≤1
406	26	16	21.0	55	0	7.7	26	1	3	2	1	1	≤1	16.1	75	1	3	0	1	≤1
407	30	14	22.0	35	0	8.7	35	1	3	3	0	1	≤1	17.1	92	1	3	0	1	≤1
408	30	13	21.5	39	0	8.2	43	1	3	2	0	1	≤1	16.6	109	1	3	0	1	≤1
409	30	18	24.0	47	0	10.7	54	1	3	3	0	1	≤1	19.1	128	1	3	0	1	≤1
410	31	18	24.5	49	0	11.2	65	1	3	2	0	1	≤1	19.6	148	2	3	0	1	≤1
411	32	19	25.5	58	0	12.2	77	1	3	2	1	1	≤1	20.6	168	2	2	0	1	≤1
412	33	19	26.0	69	0	12.7	90	1	3	2	2	1	≤1	21.1	189	2	2	1	1	≤1
413	33	20	26.5	67	5	13.2	103	1	3	2	2	1	≤1	21.6	211	2	2	1	1	≤1
414	31	20	25.5	37	1	12.2	115	1	3	2	0	1	≤1	20.6	231	2	2	0	1	≤1
415	31	20	25.5	54	0	12.2	127	1	3	2	1	1	≤1	20.6	252	2	2	0	1	≤1
416	23	16	19.5	90	22	6.2	133	1	2	2	2	1	≤1	14.6	267	3	2	2	1	≤1
417	17	15	16.0	93	6	2.7	136	1	1	1	2	1	≤1	11.1	278	3	1	2	1	≤1
418	17	15	16.0	86	3	2.7	139	1	1	1	3	1	≤1	11.1	289	3	1	2	1	≤1
419	19	15	17.0	81	4	3.7	143	1	1	1	3	1	≤1	12.1	301	3	1	3	1	≤1
420	22	16	19.0	77	2	5.7	148	1	2	2	2	1	≤1	14.1	315	3	2	2	1	≤1
421	26	16	21.0	79	1	7.7	156	1	3	2	2	1	≤1	16.1	331	3	3	2	1	≤1
422	28	20	24.0	86	2	10.7	167	1	3	3	3	1	≤1	19.1	350	3	3	2	1	≤1
423	29	21	25.0	80	5	11.7	178	1	3	2	2	1	≤1	20.1	370	3	3	2	1	≤1
424	31	23	27.0	80	1	13.7	192	1	3	2	3	1	≤1	22.1	392	4	2	3	1	≤1
425	30	24	27.0	83	1	13.7	206	1	3	2	3	1	≤1	22.1	414	4	2	3	1	≤1
426	30	24	27.0	84	8	13.7	219	1	3	2	3	1	≤1	22.1	437	4	2	3	1	≤1
427	30	24	27.0	73	8	13.7	233	1	3	2	2	1	≤1	22.1	459	4	2	2	1	≤1
428	30	24	27.0	83	6	13.7	247	1	3	2	3	1	≤1	22.1	481	4	2	3	1	≤1
429	31	24	27.5	81	1	14.2	261	1	2	2	3	1	≤1	22.1	503	4	2	3	1	≤1
430	32	24	28.0	91	8	14.7	276	1	2	2	2	1	≤1	22.3	526	4	2	2	1	≤1

Note: A = addult, E = egg, P = Pupae, La = Larvae, Ge = Generation, P^T = Predict with temperature, P^{RH} = Predict with relation humidity, P: final predict, O = Result of observable fields, Pre: precipitation

3.1.2. Predicting the growing ability of the budworm

Evaluating based on Degree-Days: In April, the accumulated growing degree days of the budworm in Cao Bang province in April reaches 276^{o}C (Table 2). With this ADD, the tobacco budworms can not complete their life cycle. To complete their life cycle, ADD has to take 413.3^{o}C. So generations and amount of the budworms will reduce strongly in the tobacco field in April, and budworms only damage the 1 level (Active and very light damage). We see that the growth of the budworm heavily depends on the temperature, especially the low temperature that decreases the accumulated degree days. Degree Days are accumulated between the established lower and upper threshold temperatures over the time interval for the developmental event of interest in the species' life history, e.g. development from egg to adult in insects (Huber 1982; Peddu et al., 2020), particularly exhibit direct relationship to the development rate of insect larvae (Fand, B. B et al., 2014; Fand, B. B et al., 2015). Each organism species takes quite a long time to grow a given amount or to develop through successive stages at low temperatures. Temperature increases and development time progressively decreases until the temperature becomes high enough to affect that growth and development negatively; requires a set of ^{o}D to complete development (Lloy T. Wilson and William W. Barnett, 1983). These relationships are used to predict developmental insects in the field (Babasaheb B. Fand, 2021).

Evaluating based on weather conditions: The weather change such as temperature, humidity, precipitation etc. impacts the growth, development and multiplication of insects (Somala Karthik et al., 2021). They develop rapidly in warm, and the population can build up quickly when the weather is favourable. Heavy and prolonged periods of rain can substantially reduce the heavy insect population (Rafiq et al., 2008). Following weather data for April 01 - 19, the average temperature is 20.7^{o}C, the low average temperature is 15.5^{o}C, in that the lowest temperature of days is approximate to the base development temperature (13.3^{o}C) which decreases strongly the development of the budworm in the tobacco field. In addition, the relative humidity of April 01 - 15 is low oscillating from 35 - 68%. Relative humidity affects the physiology of the development, longevity and oviposition of many insects, particularly at low relative humidities (Gullan and Cranston, 2005; Guarneri et al., 2002). From April 22 to 30, the temperature and relative humidity are proper for the quick development of the budworm with temperature levels of 24 - 27^{o}C and humidity of 80 - 86% (Topt: 21 - 27^{o}C and RH = 80 - 85%). However, from April 13 - 30, all days appear a little rain to heavy rainy and prolonged periods that prevent the flight, sex, reproduction, and hatching ability of adults and reduce strongly the population of insects in the field. Outside the end days of April, tobaccos begin to harvest, cut off tops, and kill the buds which are unfavourite for active insects.

The growth and development of insects affect severely by temperature and humidity because they are cold-blooded animals and their body with a lot of water. At low relative humidities, their development may be retarded, or larvae at 1 or 2 instars may be dead as they can not moult to 2 instars and 3 instars (Gullan and Cranston, 2005), preventing embryo development and egg hatching due to loss of lubrication and cuticular softness in insect (Guarneri et al., 2002). At high relative humidities or in saturated air (RH=100%), insects or their eggs may drown or be infected more readily by pathogens (Gullan and Cranston, 2005). Environmental temperature and humidity affect the developmental phase and transpiration through the insect body surface (Chapman 1998; Guarneri et al., 2002). Insects must keep body water content within certain limits which is influenced by the degree of the insect cuticle permeability (Willmer, 1982; Raghu et al., 2004). Insect survival is influenced by its ability to tolerate fluctuations in body water influenced by humidity (Romoser and Stoffolano, 1998).

Based on the evaluation of degree-days and weather conditions in April, predicting the tobacco budworm only develops at 1 level, with active and very light damage. The result of scouting showed that the budworms only appear with a damage rate of under 1%. The control methods: Kill the budworms by manual measures and do not use pesticides to control them.

3.1.3. Predicting the growing ability of the aphid

Evaluating bases on Degree-Days: Accumulated degree-days of the aphid reach 526^{o}C in April (Table 2) and complete 4 life cycles on the tobacco because to complete the life cycle, aphids take 130^{o}C. At the end stage of April, tobaccos begin the harvest and cut off tops which are not proper for the aphid. Because at this stage, the leaf is old and mature and aphids will emigrate to the favourable hosts.

Evaluating based on weather conditions: In the first and middle days of April, cold temperature and low relative humidity are less favourable for tobacco aphids to develop quickly. Particularly, the RH of April 01 - 15 is very low, oscillating from 35 to 68% which inhibits the growth of aphids, with a growth level of aphids being 0 to 1 (no active to active and light damage). On the end days of the month, temperature and relative humidity gradually increase which are favourable for aphids to develop, but it appeared heavy and prolonged periods of rain and wind wash away aphids from plants. When heavy rain and wind dislodged aphids, reduced strongly the population density after rain events (Walid Kaakeh et al., 1993, Wallin & Loonan, 1971). Walid Kaakeh et al., 1993, the amount and frequency of rain during the growing season play an important role in controlling aphids.
Based on the evaluation of Degree-Days and weather in April, predicting the aphids only develop at 1 level, with active and very light damage. Results of counting showed that they occur and harm the light. Control methods: Continuing to see the aphids in the tobacco field and not use pesticides to control them.

3.2. Forecast the Powdery mildew (Erysiphe cichoracearum)

3.2.1. Biological information about the Powdery mildew

Powdery mildew has been causing seriously in tobacco from spring 2019 to 2021 in Cao Bang on all tobacco varieties. To manage the disease effectively, the early forecast is an important role in tobacco cultivation. Powdery mildew appears in the tobacco field when cool temperature, high relative humidity, very light rain or drizzling rain, leaf wetness hours over 24 hours, cloudy, overcast, scattering light, and light wind. Powdery mildew will break out and injure severely in a short time, approximately 2 - 3 days when all conditions are favourable. The data in table 3, powdery mildew develops heavily at the temperature during 20 - 24^{o}C, RH: 85 - 90%, and leaf wetness hours: $\geq$ 24 hours, outside those conditions, the development of the disease gradually decreases. No development when temperatures are below 11^{o}C and above 32 ^{o}C. When leaf wetness is too high or the relative humidity is too low, spores of *E. cichoracearum* are dead. Remigio A Guzman-Plazola et al., 2003, the optimal humidity of the growth and germination of fungi is range from 80 - 90%, and temperature from 24 - 26^{o}C, Sijo Joseph et al., 2019: temperature: 20^{o}C and humidity: 80 - 85%. If it is over 95% and below 70%, the growth and germination reduce quickly, Ralph. M. Morrison: at 18 to 24^{o}C, non-germination: < 10^{o}C and > 32^{o}C. Free water on leaf surface inhibits germination; Nagah Milod *et al.*, 2017: RH: 80 - 90%, and temperature: 20 - 25^{o}C; Craig Austin and Wayne Wilcox, 2010, powdery mildew thrives at temperatures near 26^{o}C, stops growing at temperatures above 32^{o}C, and dies at temperatures above 35^{o}C.

Table 3. The growing conditions for infection of *Erysiphe cichoracearum*

Insect information	Forecast levels				
	0	1	2	3	4
Temperature levels (TL)	< 11 > 32	11 - < 18 > 28 - 32	18 - < 20 > 24 - 28	20 - 24	20 - 24***
Relative humidity (RH)%**		< 60, 100	70 - < 80, > 90,< 100	80 -< 85	85 - 90
Leaf wetness hours*		< 4	12	24	24

Leaf wetness hours: NJ Deshmukh et al., 2019, ** RH: M. B. Uloth M. P et al., 2017 and Sijo Joseph et al., 2019, * Remigio A Guzman-Plazola et al., 2003*

Table 4. Predict the Powdery mildew (*E. cichoracearum*) damaging the tobacco in Cao Bang in April, 2022

Date	Weather and climate conditions							Prediction					O
	T_{av} oC	RH %	LW (h)	ALW (h)	T^{LW} (h)	Pre (mm)	Weather	P^{T}	P^{RH}	P^{LW}	$P^{T.LW}$	P	
401	16.0	68	0	0	0	4	Light rain, Overcast	1	1	0	0	0	0
402	15.0	66	0	0	0	1	Sprinkles early, sunny	1	1	0	0	0	0
403	17.0	48	0	0	0	0	Sunny	1	0	0	0	0	0
404	16.5	52	0	0	0	0	Sunny	1	0	0	0	0	0
405	19.0	55	0	0	0	0	Clouds	2	0	0	0	0	0
406	21.0	55	0	0	0	0	Broken clouds, sunny	3	0	0	0	0	0
407	22.0	35	0	0	0	0	Decreasing clouds, sunny	3	0	0	0	0	0
408	21.5	39	0	0	0	0	Sunny	3	0	0	0	0	0
409	24.0	47	0	0	0	0	Sunny	3	0	0	0	0	0
410	24.5	49	0	0	0	0	Sunny	2	0	0	0	0	0
411	25.5	58	0	0	0	0	Sunny	2	0	0	0	0	0
412	26.0	69	7	7	21	0	Broken clouds, sunny	2	1	1	3	0	0
413	26.5	67	3	3	21	5	Light rain, cloudiness	2	1	0	3	0	0
414	25.5	37	0	0	0	1	Overcast	2	0	0	0	0	0
415	25.5	54	0	0	0	0	Breaks of sun late	2	0	0	0	0	0
416	19.5	90	24	24	18	22	Thunderstorms, Overcast	2	4	4	2	1	0
417	16.0	93	24	48	16	6	Sprinkles, Overcast	1	2	2	1	1	0
418	16.0	86	24	72	15	3	Sprinkles, Overcast	1	3	2	1	1	0
419	17.0	81	10	82	15	4	Light rain, Overcast.	1	2	1	1	1	0
420	19.0	77	16	16	17	2	Light showers, Cloudy	2	2	2	1	1	0
421	21.0	79	16	16	17	1	Light rain, Cloudy	3	2	2	1	1	0
422	24.0	86	30	30	22	2	Light showers, Sun late	3	3	4	3	1	0
423	25.0	80	13	43	22	5	Isolated storms, clouds	2	2	2	3	1	0
424	27.0	80	16	16	23	1	Light showers, Sun late	2	2	2	3	1	0
425	27.0	83	43	43	25	1	Light showers, sun late	2	2	4	2	1	0
426	27.0	84	17	17	25	8	Thunderstorms, Cloudy	2	2	2	2	1	0
427	27.0	73	17	17	24	8	Showers late, clouds	2	2	2	3	1	0
428	27.0	83	17	17	24	6	A few storms	2	2	2	3	1	0
429	27.5	81	17	17	23	1	Sprinkles	2	2	2	3	1	0
430	28.0	91	30	30	23	8	Thunderstorms, Overcast	1	4	4	3	1	0

Note: P^T= Predict with temperature, P^{RH}= Predict with relative humidity, P^{LW}= Predict with leafwetness, $P^{T.LW}$ = Predict with the temperature at leaf wetness during, P = final predict, O = Result of observable fields

Data in table 4 shows that the temperature levels in April are range from 17^{o}C to 28^{o}C and an average temperature of 22^{o}C, but it has ten days with cool temperature levels (15 - 19^{o}C) that inhibit the quick growth of *E. cichoracearum* lead to disease only develops from 1 to 2 levels (active and no damage to active and light damage). For the relative humidity on April 1 - 15, it is low, from 35 - 68%, so P^{RH} level = 0 - 1 and diseased symptoms do not appear in the tobacco. From April 16 - 30, relative humidity is a high threshold, ranging from 80 - 93% which helps fungi act and cause light to moderate damage. According to the studies of Remigio A Guzman-Plazola *et al*., 2003, low RH levels (20 - 40%) reduce germination and growth of the lesion, accelerated host tissue death and reduce diseased progress. Intermediate RH levels (50 - 70%) increase spore germination and optimized disease development (temperature is favourable) and are favourable from 80% to 90%. If the RH that continues exposure over 90 - 100% limits lesion growth and diseased progression. Free water in the leaves inhibits spore germination of *E. cichoracearum*, especially if the spores are completely immersed in the free water (Sydney Albert John Tarr, 1972). W. D. Gubler, UC Davis, and S. T. Koike, powdery mildew species can germinate and infect in the absence of free water. Water or heavy rain for extended periods inhibits germination and kills the spores of most powdery mildew fungi.

For the LW and T.LW, we see that the first 15 days of April have low relative humidity, no rainy, and sunny, adding low canopy density leading to the leaf wetness not appearing on the leaf, although the temperature is optimal for the growth of fungi. In the 15 days of the end of April, the temperature, relative humidity, and overcast gradually rise to be favourable for fungi to grow. For example, the relative humidity of most days are range from 80 - 93% and ALW on 15 days is range from 17 hours to 43 hours which is very favourable for the powdery mildew to develop quickly and cause serious damage. Leaf wetness plays an important role in the development of disease, particularly directly affecting the germination capacity of spores (Rabiu Olatinwo et al., 2014; Nguyen Van Chin, 2021; Tracy Rowlandson et al., 2015). Because spores only germinate and penetrate the leaf when the leaf surface has wetness or a very thin film of water on the leaf surface and does not require water droplets. When the surface leaves are dry, the spores can not germinate. Spores are easy to die when surface leaves are too wet or are washed out from the leaf or died when the surface leaf has a lot of water, the thick film of water or water droplets.

In addition, the growth of disease also depends on the number of rainy days, rainfall and field coverage. The spore and fungi only germinate and develop strongly when the drizzling rain prolongs for many days and it is always overcast. If heavily and prolonged periods of rain, spores are washed away and diseased symptoms are difficult to occur. Table 4 showed the weather from April 16 - 30 always has light rain to heavy rain, with total precipitation of 78 mm, and an average rainfall of 5.2 mm per day. Especially on April 16, 17, 23, 26 - 28, and 30 have showers with rainfall from 5 - 22 mm, and strong wind that washes the spores out from the leaf and reduces the infective resources in the field. Those evaluations are like some other authors such as W. D. Gubler et al., 2009 (water on plant surfaces for extended periods inhibits germination and kills the spores of most powdery mildew fungi).

In spring 2022, the tobacco grows slowly, leaf size is small and tobacco does not canopy which reduces the field humidity and leaf wetness. Because field coverage that is an important role affects the field humidity and the leaf wetness. If the high field coverage increases the field humidity, leaf wetness, and disease will be favourite to develop. Conversely, the field humidity reduces and limits the growth of the disease. In addition, in April, the tobacco begins harvest so the crop canopy gradually decreases leading to the direct sunlight and ultraviolet rays shining on the bottom leaves and killing all spores and fungi growing on the leaf, especially from April 01 - 15. According to Craig Austin and Wayne Wilcox, 2010, spores and fungi grow on the leaf surface, they are exposed to the heat of sunlight which, with sufficient intensity and duration, can kill powdery mildew colonies. Because the powdery mildew fungus lives primarily on the outside of infected tissues (most other pathogens live almost entirely within infected tissues).

Based on the above predictive analysis results, forecasting the powdery mildew only appears at 1 level, with the active and no damage. The investigative result in the field showed that symptoms of the disease do not appear in the tobacco in Cao Bang, in 2022. Some major control methods: Sanitating and destroying the weeds and the bottom leaves of the tobacco plants; cutting off the tops and killing the axillary buds thoroughly; continuing to survey the development of disease, and no use of pesticides to control it.

4. CONCLUSION

The forecast model is built based on the Skybit, Fuzzy, and Degree days which helps the tobacco farmers to control the organism species effectively, limit the use of pesticides, protect the agricultural environment, and increase the income of the tobacco growers in recent years, especially in 2022. To increase quality forcast and control, this pests forecast model will be continued studing, performing, and completing in next years in the field condition.

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