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Influence of rainfall, relative humidity, and temperature on the damage caused by the anthracnose-twister of onion

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Abstract Spatiotemporal analysis related to the disease incidence of onion anthracnose-twister caused by *Colletotrichum gloeosporioides* and *Gibberella moniliformis* in Sto. Domingo, Nueva Ecija detected an increased magnitude of the disease in barangays Concepcion, Dolores, San Agustin, San Fabian and San Francisco.The highest disease damage ratings to onions ranged of 3 (moderate damage) to 4 (high damage) on a scale of 1-5, mainly at 10 to 11 weeks after transplantation. The damage distribution revealed high hotspot regions in onion fields in the northern area of San Fabian, the southeasteastern area of Concepcion, and the central east area of Dolores, indicating a clustering of anthracnose-twister incidence. Moreover, Geographic Information System (GIS)-mapped disease damage and weather data discovered that the former had a negligible to weak influence from rainfall with values ranging from 3.57 mm to 3.64 mm, moderate to strong which influenced from relative humidity (RH) (82.86% to 83.03%), and moderate influenced from temperature (22.55 ℃ to 22.67 ℃). The regression equation using disease damage and temperature from Dolores, San Agustin, and San Fabian revealed 0.46 to 0.63 damage to decrease whenever the temperature increased. However, the equation contradicted a common theoretical assumptions between RH and disease development stated that increasing RH can promote disease development. Thus, microclimatic RH data from plant canopy or on field conditions can provide more reliable values in regression and correlation analyses as field moisture can be easily altered by farm irrigation.

Keywords: *Colletotrichum gloeosporioides*, *Gibberella moniliformis*, Weather data

Introduction

Onion (*Allium cepa* L.), also known as 'sibuyas', is an indispensable popular culinary ingredient in both domestic and foreign cuisine. It is usually planted as a second crop to rice, corn, cucurbits, and other vegetables. Commonly grown onions are bulb onions (*e.g.*, red creole and yellow granex)

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which are grown from seeds and multiplier onions which are raised from bulbs which in turn produce multiple shoots, each of which forms a bulb (PSA, 2014a). Onions are being grown in about 14,861 hectares (ha) of agricultural land in the country. Fifty percent (50%) of the production areas are in Central Luzon with 7,407 ha. In 2015, ninety-nine percent (99%) of the Central Luzon's onion production came from Nueva Ecija (PSA, 2015). Among the 32 municipalities and cities of Nueva Ecija, Sto. Domingo is one of the onion-producing towns with 399.24 hectares of agricultural land (8688.19 ha) being planted with onions. The onion industry is one of the largest contributors to the domestic vegetable earnings of the Philippines amounting to P6.7 B at the current prices in 2018 (PSA, 2019). However, production is experiencing some decrease, which was attributed to unfavorable weather conditions such as excessive rains that greatly caused excessive soil moisture and occurrence of fungal diseases (PSA, 2014b).

Among onion diseases, anthracnose-twister contributes to low production and is currently considered the most destructive onion disease of onion in the country, causing yield losses of as high as 80% to 100% (Alberto *et al*., 2002; Alberto *et al*., 2001). Soil or airborne pathogens cause the disease, which is characterized by severe twisting of leaves and neck elongation as well as necrosis of leaves (Roguel *et al*., 2004). Alberto (2014) identified that *Colletotrichum gloeosporioides* cause the anthracnose symptom, while *Gibberella moniliformis* is suspected to be the cause of twisting and abnormal neck elongation due to excessive accumulation of gibberellins in onions (Alberto, 2014).

Information on the relative distribution and damage of the disease in onion-growing areas in Sto. Domingo, Nueva Ecija using the Geographic Information System (GIS), as well as the effect of weather conditions on the disease remains undocumented. Thus, the study was conducted to map the onion anthracnose-twister disease in the municipality, thus determining the distribution pattern of damage and the influence of rainfall, RH, and temperature on the disease; which can be used to evaluate the disease.

Materials and methods

GIS mapping of plant disease is a method to assess the severity of infestation in crop production areas. Thus, incorporating geographic and scientific data like weather parameters and disease damage to GIS is an ideal technique in assessing the level of infestation and distribution pattern of anthracnose-twister disease in onion growing areas and in creating disease infection-risk model maps.

Selection and characterization of study sites

The study area was the onion growing area of Sto. Domingo, Nueva Ecija. In 2019, the Municipal Agriculture Office of Sto. Domingo identified 12 barangays that grow onions, namely; Dolores (109.75 ha), San Agustin (74.45 ha), San Fabian (54.79 ha), Concepcion (53.05 ha), San Francisco (47.03 ha), Comitang (25.40 ha), Baloc (14.80 ha), Sto. Rosario (11.25 ha), Malayantoc (4.90 ha), Sta. Rita (2.50 ha), Malasin (1.00 ha) and Buasao (0.32 ha). The selection of the study site was based on the incidence of anthracnose-twister in onion. Onion is the dominant crop in the agricultural lands of the identified study site, which was found to have high severity level of anthracnose-twister. The major problem in the study site being selected was the infection of anthracnose-twister in onion-growing areas which resulted to low production of onions. Onion fields were digitized using Google Earth satellite imagery (Figure 1).

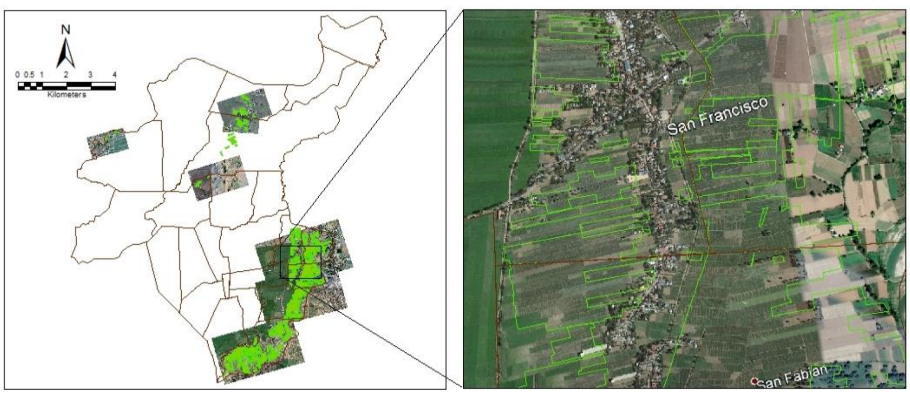


Figure 1. Digitized onion fields through Google Earth satellite imagery

Field surveillance and monitoring

Random sampling of three onion plants using a modified zigzag pattern was followed by walking near the plotted sampling points that accurately represented the extent of anthracnose-twister infection of onion in the fields, and the plants were visually inspected for the characteristics of anthracnose-twister symptoms to identify the severity level of the infected onion. Each sample plant was scored based on a 0-9 scale and was calculated using equations by Alberto (2014). The sampling population was based on the incidence of onion infected with anthracnose-twister. The recorded disease incidence and severity of onion anthracnose based on the tabulated scale was used to get the average to generate onion field disease incidence and severity classification, which in turn was used to determine the disease damage rating.

Weather data

Weather conditions such as rainfall, relative humidity, and temperature provided the disease with the required atmospheric conditions for spore germination, vegetative propagation, maturation, and reproduction of the pathogens, thereby allowing the infection, colonization, and multiplication of the disease in the crop. Daily weather data from the National Aeronautics and Space Administration - Prediction of Worldwide Energy Resources (NASA POWER) Data Access Viewer was processed in the ArcGIS software to generate a series of raster layers of rainfall, relative humidity, and temperature.

Data processing and data analysis

ArcGIS 10.3.1 software was used to facilitate GIS-based processing, analysis, and integration of spatial data. GIS provides a solution where mapping is performed for disease detection, incidence, severity, damages, and hotspots of diseases. A matrix of the status levels of onion anthracnose-twister infection wass used to merge the classification of disease incidence and severity of disease damage (Table 1). Onion shapefiles processed from Optimized Hot Spot Analysis were loaded and processed using Empirical Bayesian Kriging (EBK) under Geostatistical Analyst Tool, which further generated an interpolated raster. Field disease evaluation data from a handheld Global Positioning System (GPS) and weather data awee statistically analyzed using the version 2.0.1 software of the Statistical Tool for Agricultural Research (STAR) and were interpreted using the stratified interpretation of the correlation coefficient by Schober *et al*. (2018). The analyzed data were entered into GIS to generate a disease damage map of onion infected with anthracnose-twister and disease infection-risk model maps.

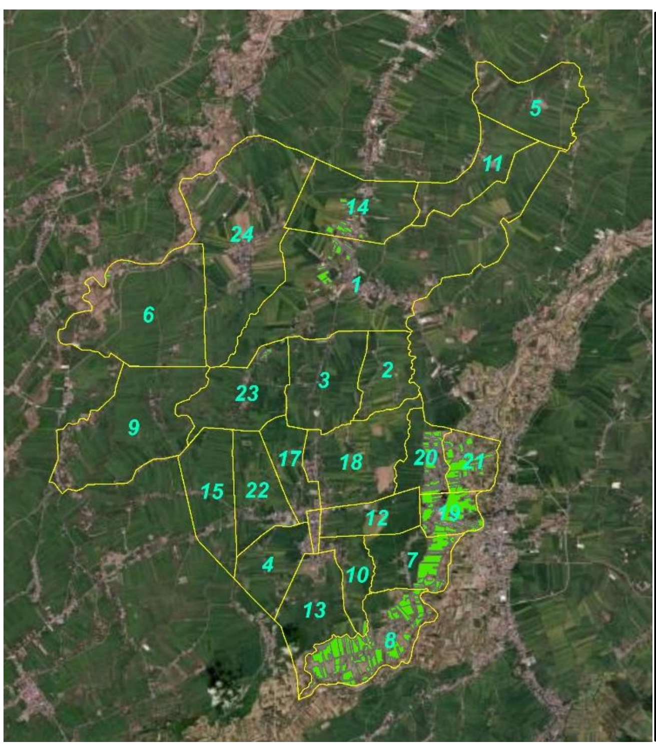
Table 1. Matrix of the status of the level of onion anthracnose-twister infection

Incidence Level	Severity	Disease Damage (Hotspot Code)	Damage Level (Hotspot Status)
No	No	1	Healthy
Low	Low	2	Very Low
Low	Moderate	2	Low
Low	High	2	Low
Moderate	Low	3	Moderate
Moderate	Moderate	3	Moderate
Moderate	High	3	Moderate
High	Low	4	High
High	Moderate	4	High
High	High	4	High
Very High	High	5	Very High

Results

Description of the study area

The municipality of Sto. Domingo is located in the central-east part of Nueva Ecija (Figure 2). It consists of 24 barangays, wherein most of its land is devoted to agriculture due to its arable land cover. There were 10 barangays that totalled an onion production area of 382.33 ha namely; Baloc, Comitang, Concepcion, Dolores, Hulo, Malayantoc, San Agustin, San Fabian, San Francisco, and Sta. Rita were monitored during the study (2019-2020 cropping season). Onions have been widely cultivated in barangays such as Dolores, San Agustin, San Fabian and San Francisco, while rice is the dominant crop from the seven other onion growing areas. Flatbed onion cropping using transplanting has been the prevalent practice in the onion-growing areas of Sto. Domingo except for the barangay Baloc where onions are grown using airplot-direct seeding methods. Red creole is the main variety of bulb onions grown in Sto. Domingo, although there are small fractions of fields planted with yellow granex too.



Name	Barangay
1	BALOC
2	BUASAO
3	BURGOS
4	CABUGAO
5	CASULUCAN
6	COMITANG
7	CONCEPCION
8	DOLORES
9	GEN. TINIO
10	HULO
11	MABINI
12	MALASIN
13	MALAYA
14	MALAYANTOC
15	MAMBARAO
16	POBLACION
17	PULONG BULI
18	SAGABA
19	SAN AGUSTIN
20	SAN FABIAN
21	SAN FRANCISCO
22	SAN PASCUAL
23	STA. RITA
24	STO.ROSARIO

Figure 2. Location of onion fields in Sto. Domingo, Nueva Ecija

Spatial and temporal distribution of anthracnose-twister disease

Among the ten barangays were weekly monitored in the 13 weeks of surveillance and monitoring from December 01, 2019 to March 16, 2020; Concepcion, Dolores, San Agustin, San Fabian, and San Francisco which found the five barangays detected with 50 individual fields (15.59 ha in total) which are affected by the anthracnose-twister disease (Figure 3 and Table 2). The affected fields were located on the southeastern side of Sto. Domingo.

Figure 3. Anthracnose-twister symptom in onion caused by *Colletotrichum gloeosporioides* and *Gibberella moniliformis* a-c) scale 7 and d-f) scale 9

Hotspot analysis of anthracnose-twister infestation

Anthracnose-twister incidence and its rate of spread in onion growing areas of Sto. Domingo, Nueva Ecija recorded spatial heterogeneity in each location. The homogeneity of status among onion fields was the definitive factor that represented cold and hotspots in the infected onion areas. The results from Empirical Bayesian Kriging-Hot Spot Analysis showed that the red areas indicated significantly hotspots, while the green represents the cold spot areas.

The hotspot map also showed the spatial distribution pattern and the degree of clustering of anthracnose incidence in Sto. Domingo, Nueva Ecija. The generated map (Figure 4) from the hot spot analysis in the 13th survey (February 27-March 02, 2020) represented hot spot areas of anthracnose-twister disease. It was detected that the northern area of onion fields from San Fabian, the southeast onion production area in Concepcion, and the central east area of Dolores had high hot spot areas of the disease as represented by a red mask. Moderate hot spot areas of the disease represented by orange and yellow masks were observed in Concepcion, Dolores, San Agustin, San Fabian, and San Francisco. Onion fields in Baloc, Comitang, Hulo, Malayantoc, and Sta. Rita with no actual recorded disease incidence and are remotely situated from the infected fields that had green hot spot masks which represented areas showed low risk for anthracnose-twister incidence. Natural barriers, sound pest management practices, and the application of preventive protective and systemic fungicides by farmers resulted green masks.

Influence of weather conditions affecting disease damage of anthracnose-twister

The temporal distribution of disease damage in onion fields per barangay was affected by rainfall, relative humidity, and temperature. Based on the data integration (Figures 5-9 and Table 3). It showed that the barangays reached their peak damage rating on the 10th to 11th survey with disease damage rating ranged from 2.8 or 3 (moderate damage) to 3.5 or 4 (high damage) as affected by rainfall ranging from 2.22 mm to 3.45 mm, RH ranging from 79.86% to 82.56%, and temperature ranging from 22.13 $^{\circ}$C to 22.25 $^{\circ}$C.

Table 2. Anthracnose-twister disease rating (%) in the five onion-growing barangays of Sto. Domingo

Barangay Onion Production	**Infected Onion Production Area (ha)**	**Anthracnose-twister Disease Rating (%)**			
		Incidence		Severity	
		Initial	Peak	Initial	Peak
Concepcion (51.16 ha)	1.21	1.41 (5th Survey)	37.69 (11th Survey)	2.05 (5th Survey)	41.21 (11th Survey)
Dolores (133.20 ha)	2.03	13.10 (6th Survey)	37.22 (10th Survey)	12.86 (6th Survey)	38.97 (11th Survey)
San Agustin (76.39 ha)	4.07	7.85 (5th Survey)	52.91 (10th Survey)	6.72 (5th Survey)	53.43 (10th Survey)
San Fabian (29.78 ha)	4.33	5.17 (5th Survey)	54.86 (10th Survey)	9.43 (5th Survey)	53.66 (10th Survey)
San Francisco (55.77 ha)	3.95	3.40 (5th Survey)	38.06 (11th Survey)	5.57 (5th Survey)	53.09 (10th Survey)

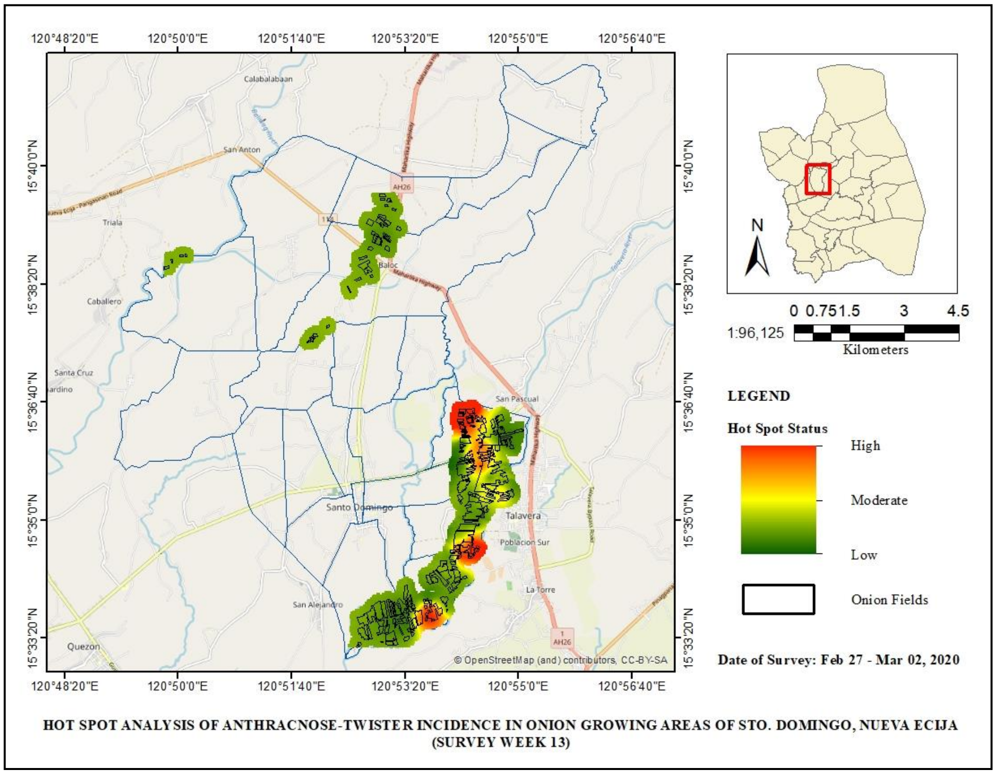


Figure 4. Map of hotspot areas of anthracnose-twister in Sto. Domingo, Nueva Ecija on 13th week of survey (February 27 – March 02, 2020)

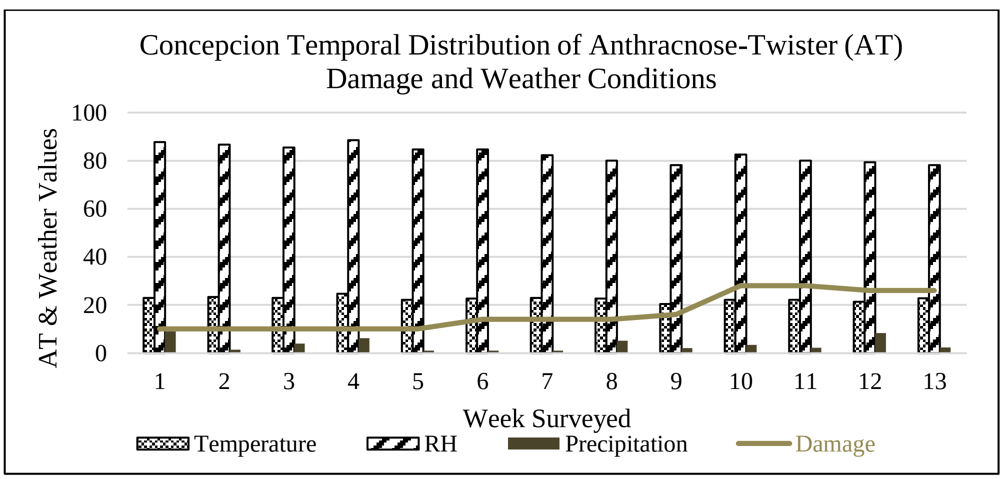


Figure 5. Temporal distribution of anthracnose-twister as affected by weather factors in Concepcion, Sto. Domingo

Table 3. Temporal integration of the peak damage rating to the weather conditions

Barangay	Anthracnose-Twister Peak		Rainfall (mm)	RH (%)	Temperature (°C)
	Week Surveyed	Rating			
Concepcion	10th - 11th	2.80	2.22 - 3.38	80.05 - 82.56	22.13 - 22.16
Dolores	10th	2.83	3.38	82.56	22.13
San Agustin	10th	3.25	3.39	82.43	22.18
San Fabian	10th	3.56	3.45	82.52	22.19
San Francisco	10th - 11th	2.89	2.26 - 3.41	79.86 - 82.36	22.22 - 22.25

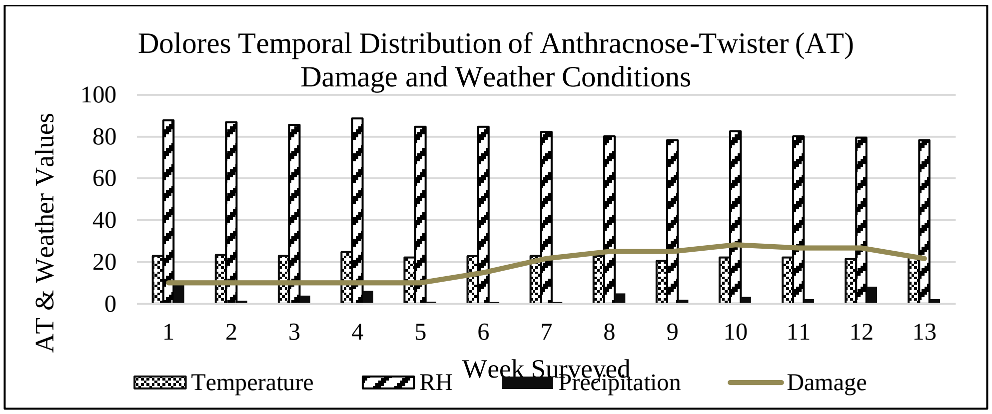


Figure 6. Temporal distribution of anthracnose-twister as affected by weather factors in Dolores, Sto. Domingo

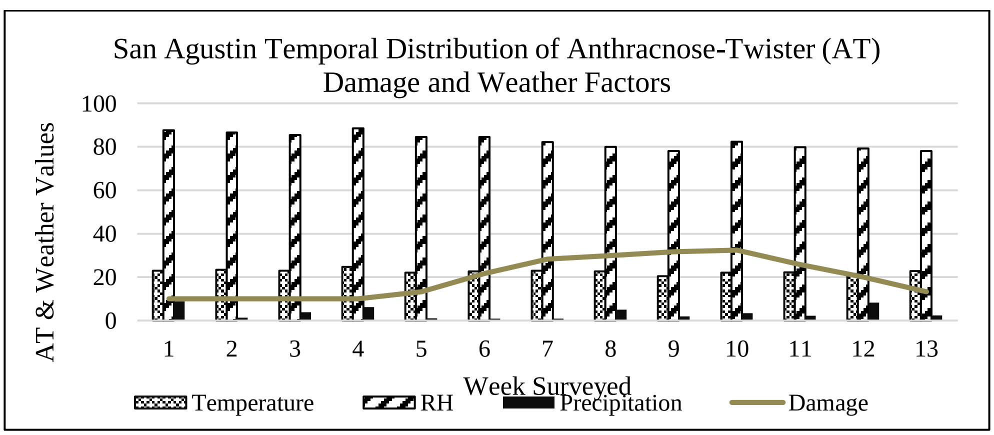


Figure 7. Temporal distribution of anthracnose-twister as affected by weather factors in San Agustin, Sto. Domingo

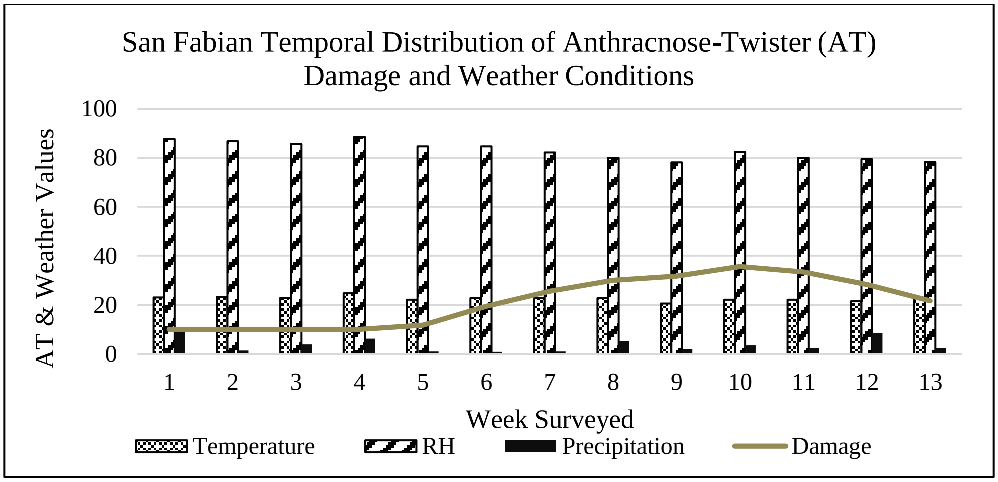


Figure 8. Temporal distribution of anthracnose-twister as affected by the weather factor in San Fabian, Sto. Domingo

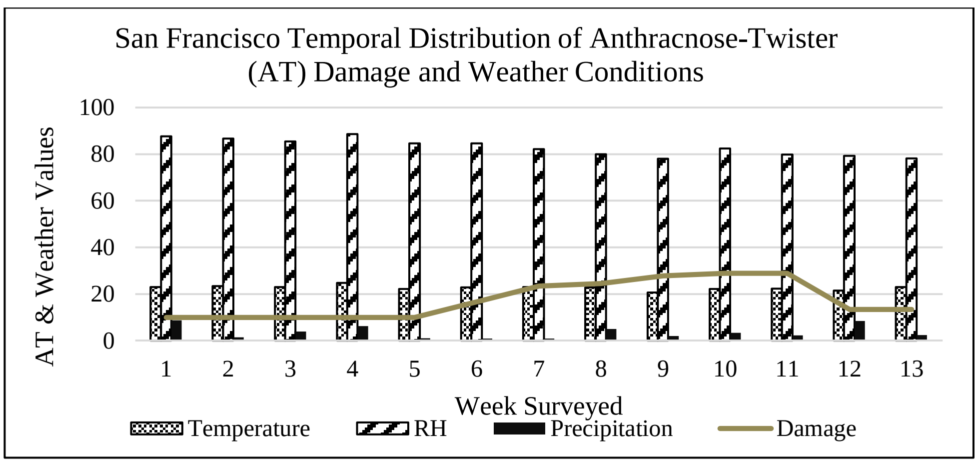


Figure 9. Temporal distribution of anthracnose-twister as affected by weather factors in San Francisco, Sto. Domingo

The analysis of variance (ANOVA) determined the significance of the model fitted. Through these analyzes, the degree and strength of the relationship between the variables were quantitatively identified and explained (Tables 4-6). Based on the statistical analyses of the relationship between disease damage and weather factors, it showed that anthracnose-twister damage and rainfall was not statistically significant with negligible to weak correlation. RH, on the other hand, was statistically significant with moderate to strong correlation. Lastly, the relationship between temperature and disease damage was statistically significant to temperature from the data of barangay Dolores, San Agustin, and San Fabian while statistically nonsignificant differences in barangay Concepcion and San Francisco. The disease damage correlation with temperature in Dolores, San Agustin, and San Fabian were moderate, wherein the generated regression equation from the statistically significant variables indicated as 0.46 to 0.63 which decreased in every ℃ increased in temperature.

Table 4. Interpretation of statistical analyses of the relationship between disease damage and rainfall

Barangay	Average Rainfall (mm)	Regression Equation	Coefficient of Correlation (R)	Correlation Interpretation
Concepcion	3.60 ^{ns}	y=2.69+0.0012x	0.004	negligible
Dolores	3.57 ^{ns}	y=1.90-0.01x	0.0026	negligible
San Agustin	3.59 ^{ns}	y=2.27-0.08x	0.2512	weak
San Fabian	3.64 ^{ns}	y=2.2.8-0.04x	0.1095	weak
San Francisco	3.59 ^{ns}	y=2.05-0.08x	0.2902	weak

Note: ns = nonsignificant effect

Table 5. Interpretation of statistical analyses of the relationship between disease damage and RH

Barangay	Ave. RH (%)	Regression Equation	Coefficient of Correlation (R)	Correlation Interpretation
Concepcion	83.01**	y=13.87-0.15x	0.7095	strong
Dolores	83.03**	y=17.05-0.18x	0.8611	strong
San Agustin	82.91*	y = 15.493-0.163x	0.4291	moderate
San Fabian	82.99**	y=20.95-0.23x	0.8184	strong
San Francisco	82.86*	y=13.13-0.14x	0.6294	moderate

Note: * = significant effect at 5% level; ** = significant effect at 1% level

Table 6. Interpretation of statistical analyses of the relationship betweendisease damage and temperature

Barangay	Average Temp. (^{0}C)	Regression Equation	Coefficient of Correlation (R)	Correlation Interpretation
Concepcion	22.59^{ns}	y=8.99-0.32x	0.4362	moderate
Dolores	22.55*	y=12.12-0.46x	0.5535	moderate
San Agustin	22.63*	y=13.85-0.52x	0.5814	moderate
San Fabian	22.64*	y=16.37-0.63x	0.6282	moderate
San Francisco	22.67^{ns}	y=10.92-0.40x	0.5080	moderate

Note: ns = nonsignificant effect; * = significant effect at 5% level;

Discussion

Surveillance and mapping of anthracnose-twister disease identified five onion-growing barangays in Sto. Domingo, Nueva Ecija affected by the disease; namely Concepcion, Dolores, San Agustin, San Fabian, and San Francisco. High hotspot areas of the anthracnose-twister disease were detected from the northern area of onion fields in San Fabian, thesoutheastern onion production area in Concepcion, and the central east onion area of Dolores, while moderate hotspot areas of the disease represented by orange and yellow masks were observed in Concepcion, Dolores, San Agustin, San Fabian, and San Francisco. These represented the moderate probability of the risk of onion plants being infected by the disease as sources of mature inoculum from high hot spot areas were adjacently situated. The Colletotrichum and and Fusarium pathogens; responisble for the anthracnose-twister disease, was isolated from air by Qiao *et al.* (2021) and Chen *et al.* (2020) on their recent study and was the same to what Singh *et al*. (1996) described as air borne plant pathogenic organism. The two genera were also classified as waterborne pathogen by Saxena *et al.* (2016) and Punja *et al.* (2019) in which conidia, through water splashes and irrigation, can be easily transported like in onion environment of Sto. Domingo, Nueva Ecija where farmers practice includes frequent flooding of fields to irrigate the crop and the fields were opened to the free wind. The hotspot analysis portrayed a geographical representation of areas at risk of the disease incidence as the maps express interpolation based on the actual data of incidence. The infected onion fields of the barangays in Sto. Domingo recorded a disease damage rating ranged from 3 (moderate damage) to 4 (high damage) which is negatively influenced by RH ranging from 79.86% to 82.56% and temperature ranging from 22.13 °C to 22.25 °C. However, majority of the generated regression equation from the barangays indicated to decrease 0.14 to 0.23 disease damage for every percent increased of RH, which contradicted the common theoretical assumptions that RH and rainfall promote disease progression. According to Thomas & William (2001), disease development is affected by microclimatic conditions (within the phylloplane or plant canopy) particularly within 300-400 µm boundary layer wherein fungal sporulation and liberation occurs. Opposite to the microclimatic condition is the macroclimatic (conditions present up to 2 m above ground level) which values measured in a formal meteorological and satellite station like NASA. Changes in microclimate surrounding is expected to cause changes in magnitude of disease expression in a given pathosystem and geographical distribution .Furthermore, rainfall is only one factor under moisture along with leaf wetness, dew, and relative humidity, which can be altered through farm activities, especially crop irrigation.Further study using microclimatic values of rainfall and RH as compared to macroclimatic values retrieved from NASA Data Access Viewer which was recommended to expound the information on the influence of weather conditions on anthracnose-twister disease damage as microclimatic conditions within the plant canopy directly affect the pathogen's development.

Acknowledgements

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