SPATIOTEMPORAL EPIDEMIOLOGY OF ANTHRACNOSE-TWISTER DISEASE OF ONION IN PRODUCTION AREAS OF STO. DOMINGO, NUEVA ECIJA, PHILIPPINES

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ABSTRACT: Epidemiology of anthracnose-twister disease of onion using Geographical Information System (GIS) and UAV in 10 onion-producing barangays of Sto. Domingo, Nueva Ecija was carried out from December 2019 to March 2020. The disease which is caused by the complex of *Colletotrichum gloeosporioides and Gibberella moniliformis* was identified to be a major problem in the onion production of the province. The study is initiated to determine, monitor, and map the damage, distribution, hotspot areas, and spread rate of the disease to onion fields. Through ground surveillance, five (5) barangays which include Concepcion (1.21 ha), Dolores (2.03 ha), San Agustin (4.07 ha), San Fabian (4.33 ha), and San Francisco (3.95 ha) were detected to have an increasing magnitude of disease incidence from its detection until the harvesting season. High level of disease severities was also observed from the fields wherein black concentric rings of acervuli were formed on the leaves. Disease spread from barangays which ranges from 0.06 to 0.28 percent/week was computed using the derived Vanderplank's disease formula for disease rate. Moreover, onion fields from the northern area of San Fabian, southeast area of Concepcion and central east area of Dolores showed disease high hotspot areas. Lastly, SVM-facilitated UAV classification confirms the mean reflectance of healthy onions and discriminate infected classes of onion using multispectral imaging. A 0.012 ha of onion fields were detected with anthracnose-twister infection, but, the extent of actual infected areas based on the field evaluation and interpolation recorded 0.35 ha. This entails that remotely-sensed approach of disease surveillance can offer additional tool in disease evaluation especially in larger scope of areas but still with the support of on-field evaluations and monitoring.

INTRODUCTION

Onion (*Allium cepa* L.), otherwise known as "sibuyas", is an indispensable popular culinary ingredient in both the domestic and foreign cuisine (DA, 2013). It is usually planted as a second crop to rice, (Alberto et al., 2001), corn, and cucurbits vegetables. The commonly grown onions are bulb onions (e.g., red creole and yellow granex) which are grown from seed and multiplier onions which are raised from bulbs which in turn produce multiple shoots, each of which forms a bulb (BAS, 2014). Onion industry is one of the largest contributors in domestic vegetable earnings amounting to P4.2B at current prices from January to March 2018.

Onions are grown in 14,861 hectares (ha) of agricultural land in the country. Fifty percent (50%) among the areas of production are in Central Luzon with 7,407 ha. In 2014, ninety-nine percent (70%) 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 onions producing towns with 399.24 hectares of agricultural land (8688.19 ha) planted with onions.

However, the upward fluctuation trend of country's production of onion decreased from 8.75 metric tons (MT) in 2009 to 8.70 MT in 2013 (PSA, 2014) and according to BAS (2012), its production went down further by 2.95% from 2011 to 2012. The unfavorable weather condition (55.95%) and occurrence of pest and diseases (45.83%) - (PSA, 2014) usually contributed to this phenomenon. In fact, onion anthracnose-twister caused yield losses of as high as 80% to 100% in almost all of the fields (Alberto et al., 2001b). Thus, the study was conducted to detect, monitor, and map the anthracnose-twister disease of onion in Sto. Domingo, Nueva Ecija, thereby, determining the distribution pattern of incidence, severity and spread rate of the disease that can be used in evaluating the disease.

MATERIALS AND METHODS

Geographic Information System (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 environmental factors and remotely sensed data to GIS is an ideal technique in assessing the level of infestation and distribution pattern of anthracnose-twister disease in onion growing areas as well as in creating disease infection-risk model maps through GIS predictive analysis. Data from a handheld Global Positioning System (GPS) device, UAV captured spectral signatures, and data from field observations are statistically correlated and regressed using Statistical Tool for Agricultural Research (STAR) 2.0.1 version. Analyzed data were entered into GIS to generate severity map of anthracnose-twister infected onion and disease infection-risk model maps.

Selection and Characterization of Study Site

The study area was the onion growing areas of Sto. Domingo, Nueva Ecija. Currently, there were 12 barangays identified by the Municipal Agriculture Office of Sto. Domingo that grows 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). Selection of the study site was based on the incidence of anthracnose-twister in onion. Onion is the dominant crop in agricultural lands of the identified study site which was found to have high severity level of anthracnose-twister. The major problem in study site being selected was the infestation of anthracnose-twister in onion-growing areas that resulted in low production of onion.

Data Processing and Data Analysis

GIS-based processing was used for the processing, analysis, and integration of spatial data. GIS and Remote Sensing in integrated form provide a solution where mapping for the disease detection, incidences, severity, damages, hotspots are carried out. 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. Maps of the spatial distribution of anthracnose-twister would lead the experts and farmers to actually understand the origin and causes leading to the crop infestations. Mapping the pest occurrences in areas where it can be spatially integrated with the agro-ecological zones can help in simulating the other hotspots for a similar infestation in the future.

Field Validation

Random sampling using modified Zigzag-pattern was followed by walking near the plotted sampling points that accurately represents the extent of anthracnose-twister infection in onion on the field and 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. The total number of infected plants and sampling population were counted and recorded as well. The sampling population was based on the incidence of onion infected with Anthracnose-twister. The proximity of the plant populations near the survey points was plotted as well as the field size. The approximate radius towards the plotted points wherein the populations of onions to be characterized based on the disease severity was 10m. Recorded disease incidence and severity of onion anthracnose based on the tabulated scale would get the average to generate onion field disease incidence classification and onion field disease severity classification, respectively. Percentage disease incidence and severity level were calculated using equation 1 and equation 2.

$$Disease\ Severity\ (\%) = \frac{number\ of\ plants\ infected}{total\ number\ of\ plants}\ x\ 100 \qquad \text{(eq. 1)}$$

$$Disease\ Severity\ (\%) = \frac{n(1)+n(3)+n(5)+n(7)+n(9)}{N\ x\ 9}\ x\ 100 \qquad \text{(eq. 2)}$$

where:

n= number of infected plants classified by grade
N= total number of plants examined

Calculation of Anthracnose-Twister Disease Progress

In order to compute the disease progress of anthracnose-twister, Vanderplank (1963) model of polycyclic disease progress was used; $x = x_0 e^{rt}$, wherein, x_0 is the proportion of the disease (population) at the start of epidemic, e is the base of natural logarithm, r is the apparent infection rate computed as infected plants per day, and t is the time. Since, infection rate was one of the focus of the study, Vanderplank's formula was derived into $r = (l_n (x/x_0)/t)$. Using the derived formula of Vanderplank (1963), the infection rate of anthracnose-twister on infected fields of each barangay was computed with the data of incidence per number of weeks of observations.

RESULTS AND DISCUSSION

Description of the Study Area

The municipality of Sto. Domingo is located in the central-east part of Nueva Ecija. 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 totaled 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 on 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 dominant practices in the onion-growing areas of Sto. Domingo except barangay Baloc where onions are grown using airplot-direct-seeding practices. Red creole is the major variety of bulb onions grown in Sto. Domingo, although there are small fractions of fields planted with yellow granex too.

Spatial and Temporal Distribution of Anthracnose-Twister Disease

Among the 10 barangays monitored weekly, Concepcion, Dolores, San Agustin, San Fabian, and San Francisco were the five barangays detected with 50 individual fields (15.59 ha in total) affected by anthracnose-twister incidence. The affected fields were situated on the southern east side of Sto. Domingo.

Concepcion

Among 51.16 ha of onion fields situated in Concepcion, a total of 1.21 ha from five onion fields were affected by the disease for the duration of the study (Figure 2). Overall average disease rating (Figure 1) for affected fields in Concepcion records an upward trend with an initial 1.41% low Level of Incidence (LOI) on 5th survey and peak with 37.69% moderate LOI on the 11th survey. Also, in Concepcion, a progressive increased in severity was recorded with an initial 2.05% low Level of Severity (LOS) on the 5th survey and it peaked with 41.21% moderate LOS on the 12th survey.

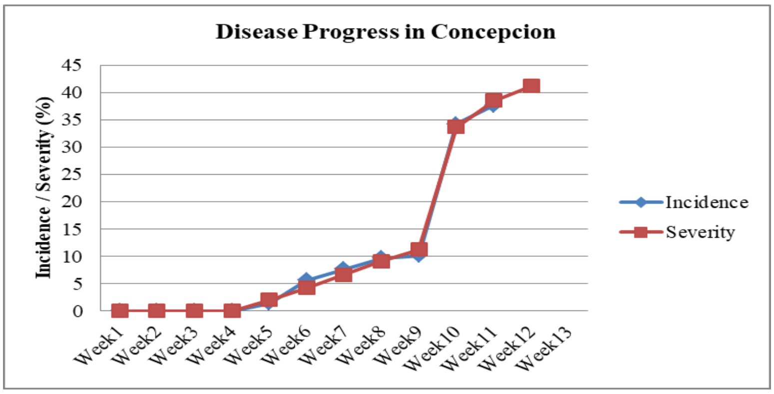

Figure 1. Disease progress in Concepcion, Sto. Domingo, Nueva Ecija

Dolores

From 133.20 ha of onion fields situated in Dolores, a total of 2.03 ha from five onion fields were affected by the disease on the duration of the study (Figure 3). Overall average disease rating for affected fields in Dolores recorded upward trend (Figure 4) with an initial 13.10% low LOI on the 6th survey and peak with 37.22% moderate LOI on the 10th survey. Also, in Dolores, a progressive increase in severity was recorded with an initial 12.86% low LOS on the 6th survey and it peaked with 38.97% moderate LOS on the 11th survey.

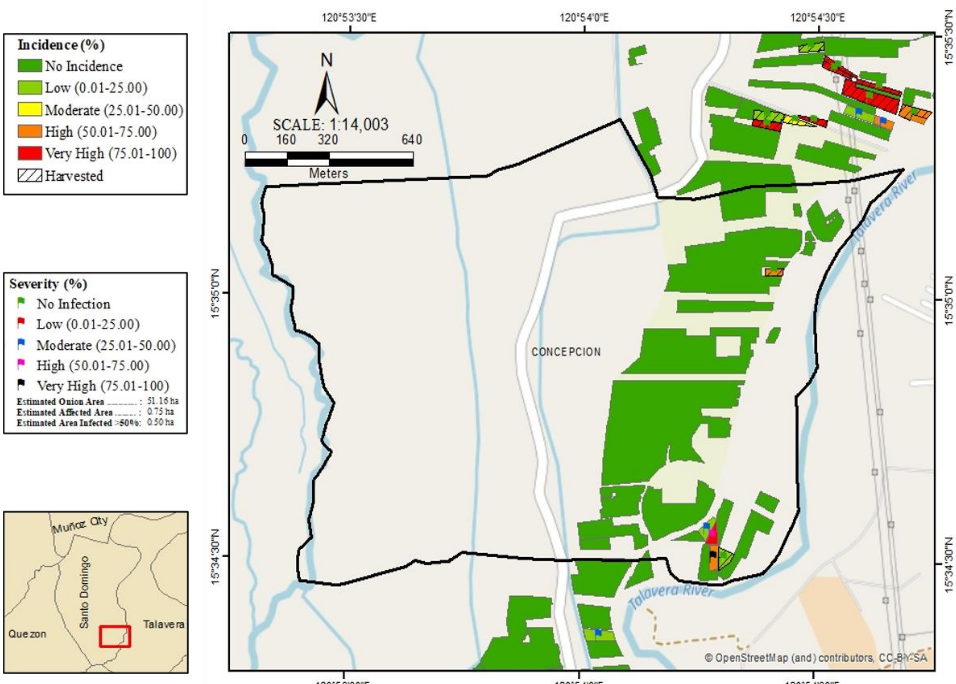

Figure 2. Thirteenth survey (February 27, 2020) map showing the status of anthracnose-twister disease of onion in Concepcion, Sto. Domingo, Nueva Ecija

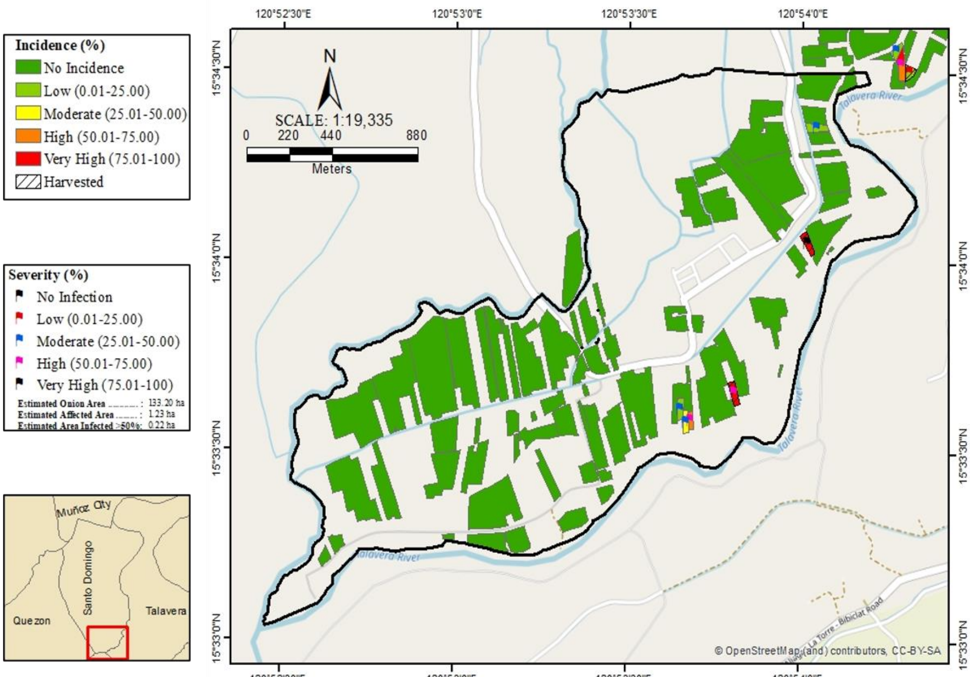

Figure 3. Thirteenth survey (February 27, 2020) map showing the status of anthracnose-twister disease of onion in Dolores, Sto. Domingo, Nueva Ecija

San Agustin

From 76.39 ha of onion fields situated in San Agustin, a total of 4.07 ha from five onion fields were affected by the disease on the duration of the study (Figure 5). Overall average disease rating for affected fields in San Agustin recorded upward trend (Figure 6) with an initial 7.85% low LOI on the 5th survey and peak with 52.91% high LOI on the 10th survey. Also, in Dolores, a progressive increase in severity was recorded with an initial 6.72% low LOS on the 5th survey and it peaked with 53.43% high LOS on the 10th survey.

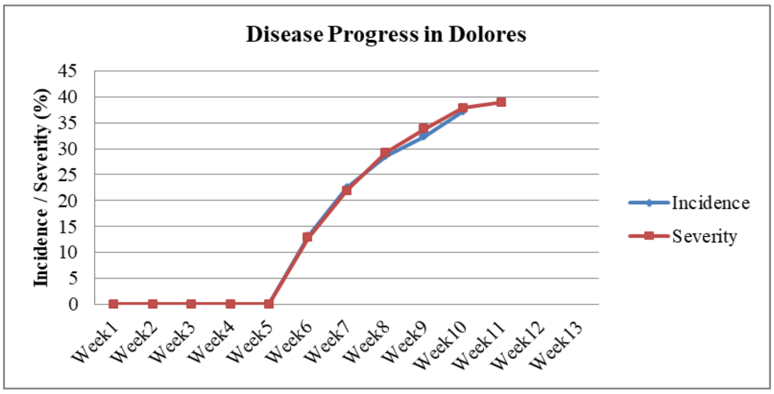

Figure 4. Disease progress in Dolores, Sto. Domingo, Nueva Ecija

Figure 5. Thirteenth survey (March 02, 2020) map showing the status of anthracnose-twister disease of onion in San Agustin, Sto. Domingo, Nueva Ecija

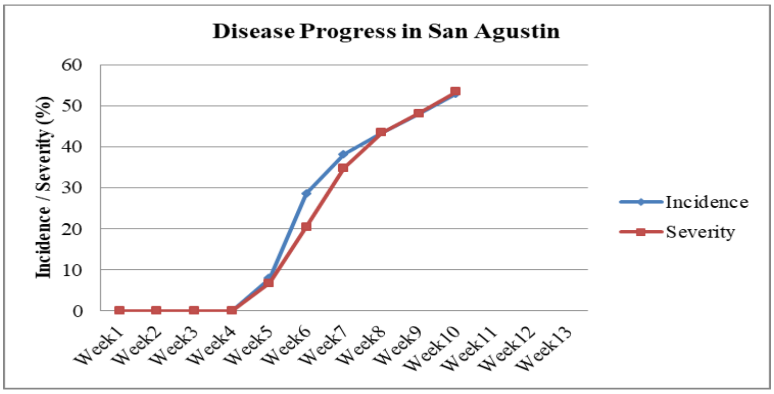

Figure 6. Disease progress in San Agustin, Sto. Domingo, Nueva Ecija

San Fabian

From 29.78 ha of onion fields situated in San Fabian, a total of 4.33 ha from 18 onion fields were affected by the disease on the duration of the study (Figure 7). Overall average disease rating for affected fields in San Fabian recorded upward trend (Figure 8) with an initial 5.17% low LOI on the 5th survey and peak with 54.86% high LOI on the 10th survey. Also, in San Fabian, a progressive increase in severity was recorded with an initial 9.43% low LOS on the 5th survey and it peaked with 53.66% high LOS on the 10th survey.

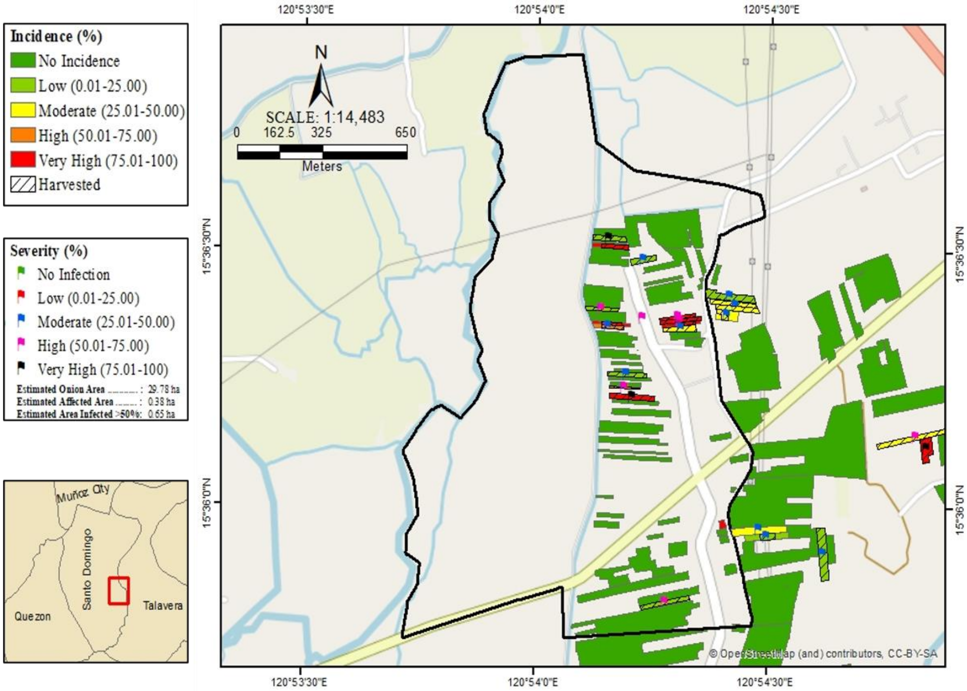

Figure 7. Thirteenth survey (February 27-29, 2020) map showing the status of anthracnose-twister disease of onion in San Fabian, Sto. Domingo, Nueva Ecija

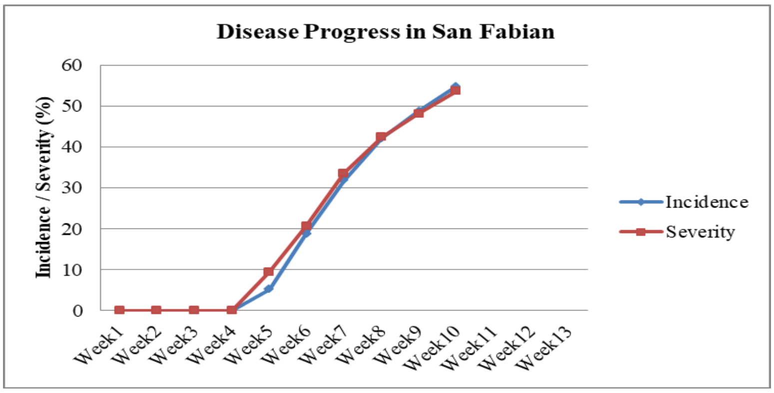

Figure 8. Disease progress in San Fabian, Sto. Domingo, Nueva Ecija

San Francisco

From 55.77 ha of onion fields situated in San Fabian, a total of 3.95 ha from nine onion fields were affected by the disease on the duration of the study (Figure 9). Overall average disease rating for affected fields in San Francisco recorded upward trend (Figure 5) with an initial 3.40% low LOI on the 5th survey and peak with 38.06% moderate LOI on the 11th survey. Also, in San Francisco, a progressive increase in severity was recorded with an initial 5.57% low LOS on the 5th survey and it peaked with 53.09% high LOS on the 10th survey.

Most of the fields were irrigated using deep well water pumps as National Irrigation Administration (NIA) irrigations are dry during cropping season. Favorable weather conditions particularly typhoons that brought excessive moisture in December as well as high relative humidity, fluctuating environmental temperatures, and intermittent rain showers throughout the cropping duration probably influenced the occurrence and magnitude of the disease.

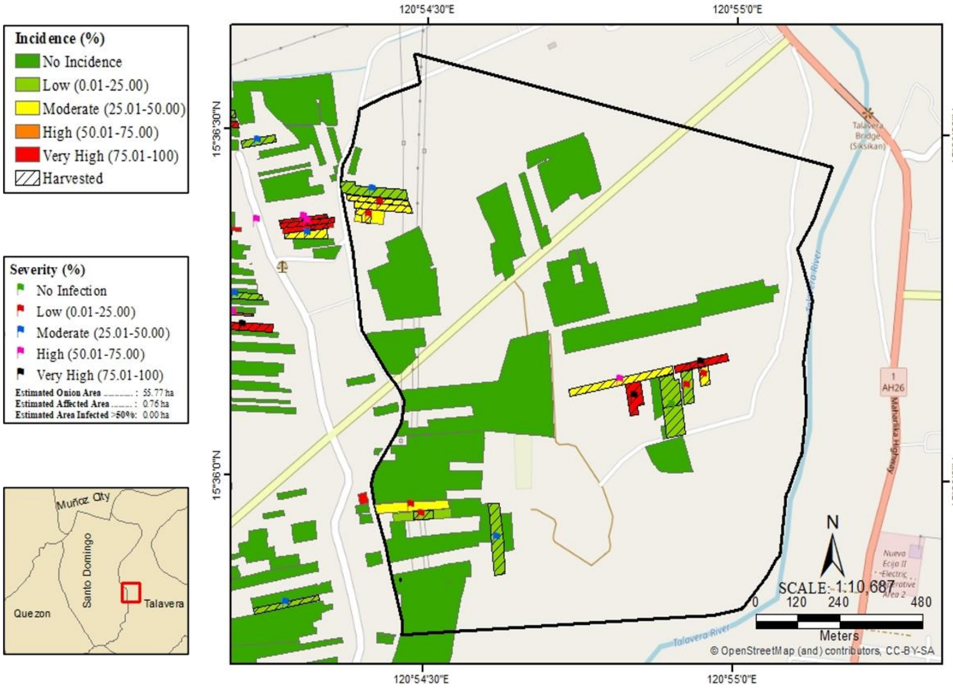

Figure 9. Thirteenth survey (February 27-29, 2020) map showing the status of anthracnose-twister disease of onion in San Francisco, Sto. Domingo, Nueva Ecija

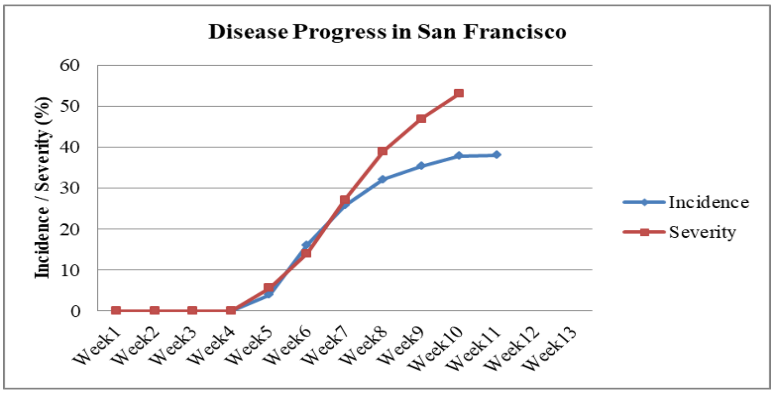

Figure 10. Disease progress in San Francisco, Sto. Domingo, Nueva Ecija

Anthracnose-Twister Disease Spread

Disease spread rate of anthracnose-twister virulence was determined using the tabulated values from each field monitoring and assessment status of onion fields within the municipality. The rate of anthracnose-twister spread was calculated using the weekly disease incidence map in the form of shapefiles or GIS data. The areas of origins were identified from each location in each affected field and a succeeding increase in area of affected adjacent fields were analyzed and recorded.

In general, based on the data provided in Table 1, all of the infected onion fields from Sto. Domingo recorded a 0.15 percent per week (%/wk) average infection rate during the disease surveillance. It was determined that during the weekly observation among the five barangays with incidences, infected onion fields from Concepcion have the highest total average of computed infection rate with a value of 0.28 %/wk. It was followed by San Francisco with 0.18 %/wk, San Agustin with 0.14 %/wk, Dolores with 0.09 %/wk, and San Fabian with 0.06 %/wk. Infection rate record from each barangay started from week 6 surveys except from barangay Dolores since incidence was first noticed on the 6th week survey. Thus, computation for its infection rate started a week after its first incidence (week 7 survey), since Vanderplank's spread rate formula requires an initial and final incidence to be computed.

Using the generated rates per barangay with prevailing favorable condition to infections and no spatial or temporal barriers, it is estimated that the time needed for the disease to reach 100% incidence from 1% incidence on the affected onion field of Concepcion (51.16 ha) would be 16.53 or 17 days, Dolores (133.20 ha) within 49.68 or 50 days, San Agustin (76.39 ha) within 32.11 or 32 days, San Fabian (29.78 ha) within 72.79 or 73 days, and San Francisco (55.70 ha) within 25.65 or 26 days.

Table 1. No. of surveillance and the computed anthracnose-twister disease spread rate (% incidence/week).

	1	2	3	4	5	6	7	8	9	10	11	12	13
Concepcion	0.0	0.0	0.0	0.0	0.0	1.38	0.85	0.64	0.49	0.08	0.001	0.06	0.12
Dolores	0.0	0.0	0.0	0.0	0.0	0.0	0.28	0.26	0.23	0.21	0.09	0.10	0.03
San Agustin	0.0	0.0	0.0	0.0	0.0	0.49	0.20	0.18	0.17	0.16	0.23	0.21	0.22
San Fabian	0.0	0.0	0.0	0.0	0.0	0.04	0.14	0.07	0.09	0.11	0.09	0.11	0.24
San Francisco	0.0	0.0	0.0	0.0	0.0	0.75	0.46	0.28	0.23	0.13	0.10	0.14	0.24

Several factors could have contributed to the resulting spread rates for each barangay. It could possibly be affected by the environmental factors, spatial distribution and density of onion fields, cultural practices employed on the field as well as direct pest management system (mostly pesticide use) which in any way could promote or inhibit disease progress on the fields. Moreover, different farming managements were employed by the farmers from each onion fields. Some of them attributed the incidence of the disease to the acidity of the soil or just generally perceived it as something wrong with the soil. A subtle correction about the real cause of the disease was presented and pointed out to the farmers as well as some management practices such as irrigation schemes to avoid excessive moisture to the field, reduction of use of nitrogen-based fertilizer to the infected areas, rogueing of infected onion plants, proper disposal away from the field, and use of protectant fungicides (Benomyl, Captan, Mancozeb) or systemic fungicides (Mancozeb, Difenoconazole, Propiconazole) with 1-2 weeks interval depending on the severity of the disease.

Hot Spot Analysis of Anthracnose-Twister Infestation

Anthracnose-twister incidence and its rate of spread in onion growing areas of Sto. Domingo, Nueva Ecija exhibits spatial heterogeneity in each location. Homogeneity of status among the onion fields was the definitive factor that represents cold and hot spot regions in the infected onion areas. Result from Empirical Bayesian Kriging-Hot Spot Analysis showed that the red areas indicate significant hotspots while green represent the cold spot areas. Hotspot map also exhibited the spatial distribution pattern and degree of clustering of anthracnose incidence in Sto. Domingo, Nueva Ecija. Generated map (Figure 12) from hot spot analysis on the 13th survey (February 27-March 02, 2020) represented hot spot areas of anthracnose-twister disease and were detected that northern area of onion fields from San Fabian, southeast onion production area in Concepcion, and central east area of Dolores have high hot spot areas of the disease as represented by red mask. Moderate to high hot spot areas of the disease represented by orange mask were observed in San Agustin and San Francisco while majority of moderate hot spot areas represented by yellow mask were observed in onion areas of San Agustin. Specifically, onion production map from Concepcion, Dolores, San Agustin, San Fabian, and San Francisco had yellow masks girdling the orange and red, hot spot masks. These represents the moderate probability of risks of onion plants being infected by the diseases as sources of mature inoculum from high hot spot areas were adjacently situated. The hotspot analysis portrays a good representation of areas at risk of the disease incidence as the maps express interpolation based on the actual data of incidence. Onion fields from Baloc, Comitang, Hulo, Malayantoc, and Sta. Rita with no actual recorded disease incidence and are remotely situated from the infected fields had green hot spot masks which represent areas that have low risk for anthracnose-twister incidence. Natural barriers, sound pest management practices, and application of preemptive protective and systemic fungicides by the farmers could possibly cause the green masks.

Unmanned Aerial Vehicle Image Classification Using Support Vector Machine (SVM)

The eCognition® software which uses support vector machine analysis was used to classify the extracted images from unmanned aerial vehicle (UAV). Multi-spectral image of the area affected by the disease was captured using and this was used as dataset to perform image classification analysis Multi-threshold segmentation and series of multi-resolution segmentation that uses vegetation indices were used. The vegetation has mean NDVI higher than 0.25 to separate from soil. Vegetation that has mean Chlorophyll Index at Red Edge (CIRE) higher than 2.0 is healthy onion, thus, vegetation class as weeds, grass or shrubs. Healthy onion with mean Soil Adjusted Vegetation Index (SAVI) lower than 0.2 are infected onion, and healthy onion/vegetation with mean Green Normalized Difference Vegetation Index (GNDVI) lower than 0.35 is classified to soil. The processed image was projected on ArcMap™ to generate a map layer. Final map of extracted onion fields including the classified onion infected with anthracnose-twister disease have a total extracted area of 1.40 ha, in which 1.39 ha was classified as healthy and 0.012 ha as infected onion areas. The right corner of the map shows the hot region (hot spot). The area of concentration of disease was verified in the multi spectral image classified in SVM.

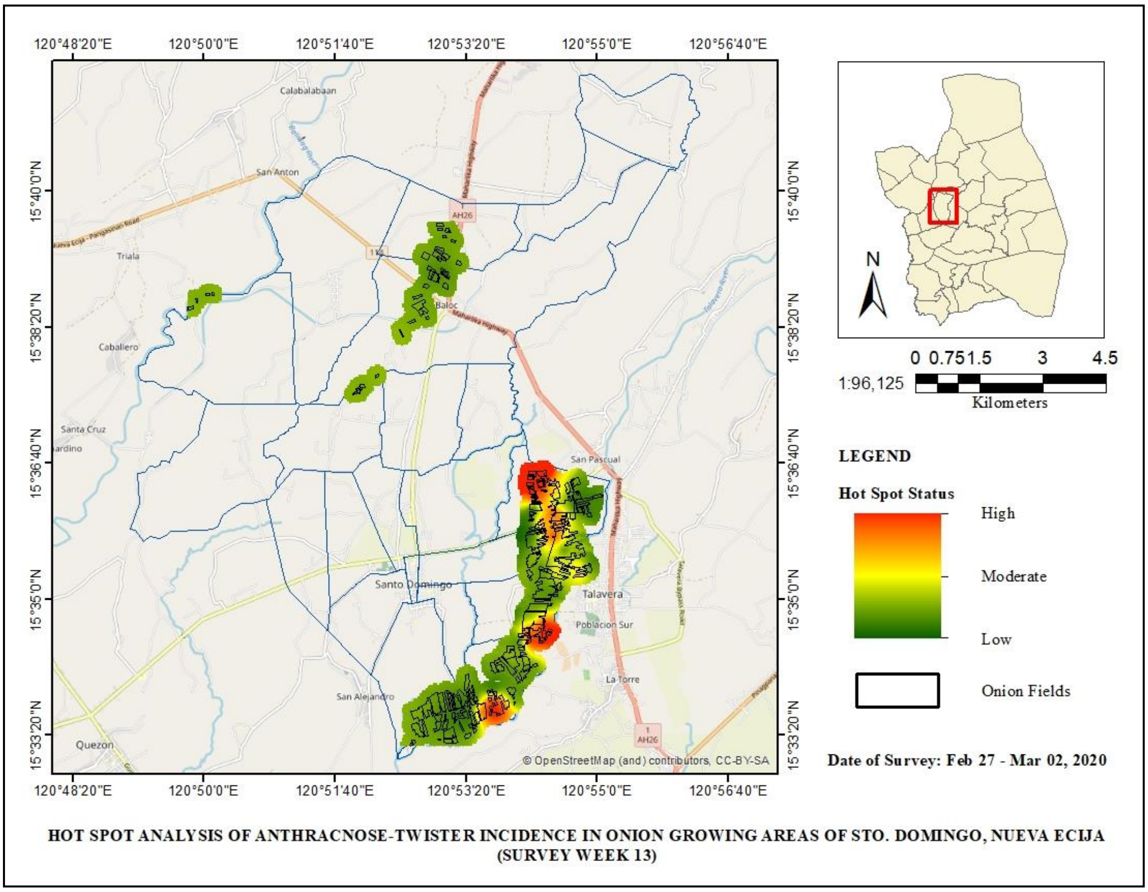

Figure 12**.** Map of hotspot areas of anthracnose-twister in Sto. Domingo, Nueva Ecija on 13th week of survey (February 27 – March 02, 2020)

The UAV image classification map generated through SVM (Figure 13) was useful in providing remotely-sensed detection of the disease. This can be useful in field surveillance with large areas covered with less manpower to conduct the field monitoring. However, the extent of actual infected areas based on the field evaluation and interpolation shows a great difference from the UAV-SVM in terms of total infected areas as the former records 0.35 ha compared to the latter with 0.012 ha.

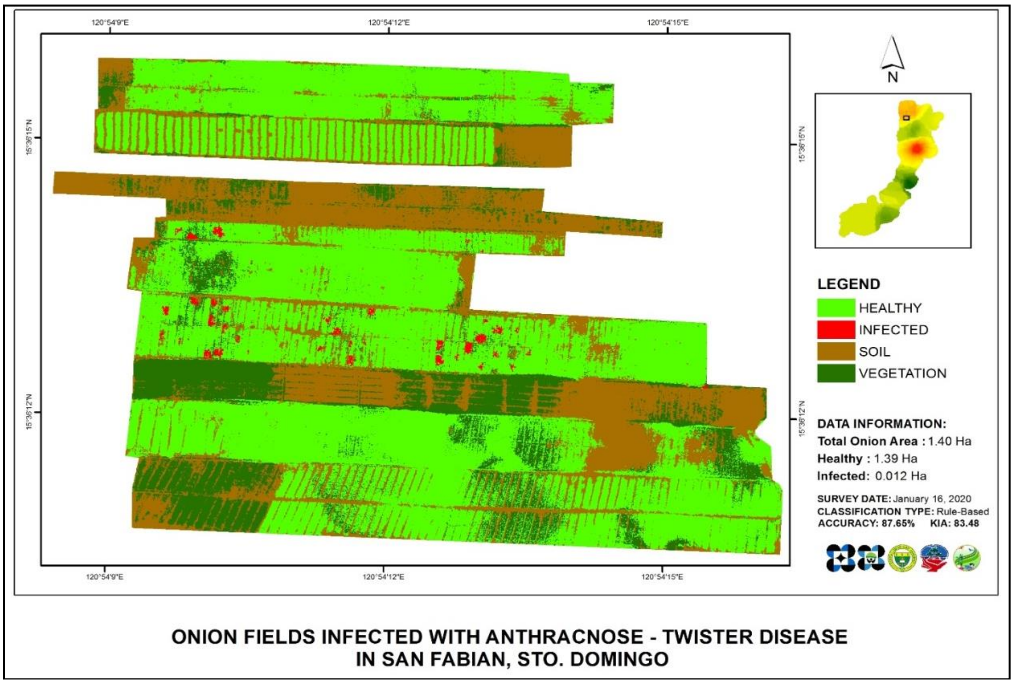

Figure 13. UAV image class map of anthracnose-twister-infected onion fields in Brgy. San Fabian, Nueva Ecija

The information contributed by this study would be useful in the holistic management approach of the disease as its pattern, and spread rate can provide basis for possible disease spread modelling and study for disease management of anthracnose-twister. The generated maps and spread rate of the disease for each barangay can be considered by the farmers for smart judicious pesticide application and the municipal agriculturists for crop disease management, thereby, preventing the occurrence, spread, and unwanted outbreaks of the disease for the succeeding growing seasons. The generated maps can also be used to spatial and temporally visualize how the anthracnose-twister poses threat to the onion production industry of the country.

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