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The Nexus between Incidence and Severity of Chili Anthracnose (*Colletotrichum capsici* (Syd.) Bisby and Butler) on Chili in SNNPR, Ethiopia

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Abstract

The incidence-severity relationship for chili anthracnose, caused by *Colletotrichum* spp., was studied on ten released Chili/pepper genotypes to determine the feasibility of using disease incidence to estimate indirectly disease severity in order to establish the potential damage caused by this disease in southern region, Ethiopia. Data were statistically analyzed by regression. Anthracnose leaf incidence was consistently associated with leaf severity and their relationships can be estimated using the linear function across locations, crop seasons, and genotypes. Thus, the use of easily assessed incidence data had been recommended for determination of severity as well as epidemic comparisons, genotype and seasonal evaluation in chili anthracnose management. This study will pave the way for chili producing farmers for cheaper and efficient approach tailoring it for determination of economic threshold level and launch opportune management practices.

***Keywords*:** Anthracnose; Chili; Incidence; i-s-Relationship; Severity.

1. Introduction

Chili anthracnose, caused by *Colletotrichum capsici*(Syd.), is one of the most important chili disease in pepper growing regions of Ethiopia [1], which manifests its symptoms in both leaves and young fruits [2].

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At its ceiling level, severity may lead to permanent wilting and senescence of leaves on mature plant leading to defoliation during shoot development, chlorosis of inflorescences and afterward necrosis and falling of young fruits [3,4] (Cardoso and his colleagues 2000; 2004). Chili anthracnose symptoms and the impact of the disease were barely described in Ethiopia [1]. Quantification of anthracnose disease is one of the most challenging tasks. The assessment of disease incidence (i.e., the proportion of diseased plants in a population) is an apparently simple counting task. The accurate and precise estimation or measurement of disease severity (i.e., the area of plant tissue that is symptomatic) formidable task [5,6]. It is tedious, time consuming and physically discomforting task.

As Campbell and Maden [6] clearly described incidence and severity, the distinction between these two measures is not always as apparent as the definitions suggest. Usually the definitions of incidence or severity rely on the sampling unit used during disease measurement [7]. In chili anthracnose quantification, this distinction is made even more difficult by the fact that disease may be assessed at different levels (field, plot, plant, pod, green fruit, and ripened fruit) within a spatial hierarchy. The incidence–severity association represents a relationship between disease intensity measured at different levels [7].

Relationships between incidence and severity at different levels of a spatial hierarchy have been developed for several pathosystems [8]. Various factors determine the relationships and differ from one pathosystem to another. The cultivar and plant organ assessed, time of disease assessment during an epidemic, growing season, location, and treatment applied to the assessed plots are some of the determinant factors [7]. Thus, it would be imprudent to use these models to describe the relationship between incidence and severity of Chili anthracnose of chili prior to thoroughly evaluating them over multiple years and locations under a range of cropping/management scenarios to ascertain which model provides consistently strong relationships between incidence and severity of this disease [9].

The relationship between measures of anthracnose intensity at different levels of a spatial scale has been studied by [8]. The former studies focused mainly on the comparison of year-to-year repeatability of disease incidence, diseased fruit severity (mean proportion of infected fruits per infected branch, or equivalently, mean relative area of infected fruit with symptoms), and disease index (equivalent to the standard definition of severity [6], as used here as measures of components of resistance to *Colletotrichum* spp. Reference [8] did not fully explore the relationship between incidence and severity from the standpoint of its practical application in disease quantification and surveys, and how it may be influenced by sampling. While the work of [8] did address issues related to practical application of the relationship between incidence and severity of Colletotrichum leaves, as was the case in the study conducted by [8], the epidemiological conditions under which this study was conducted were different from those occurring commonly in many areas. Information concerning the chili severity-incidence relationship was inadequate in major chili growing areas of SNNP, Oromia and Amhara regions of Ethiopia. Chili cultivars planted in SNNP differ from the rest of the country; the composition of the *Colletotrichum* complex inciting *Colletotrichum* spp in SNNP is generally different from that found in Oromia and Amhara regions, the latter being predominantly *Colletotrichum* spp and severity was quantified in the aforementioned studies differs from the way it is commonly done in SNNP. These factors may all influence the relationship between measures of disease intensity [8].

Typically, damage assessment can be done for fungicide or germplasm screening after identification of the causative pathogen carried out [4] or epidemiological investigations [4,10]. In any of the above approaches, terminology such as disease incidence, disease severity, disease density and others are commonly used to measure the disease. Relative advantages and practical applications of their relationships have been discussed [10]. However, realistic limitations ensuing from discrepancy of the associations across locations, stage of the epidemic, host genotype and crop cycle have been depicted [11]. Simple, consistent and useful relationships in different pathosystems had been developed [4]. As a result, tedious and time consuming work associated with severity measurement has been replaced by the easily measured incidence [4,12].

The objectives of this study were to (i) determine if there was a significant and consistent relationship between incidence and severity of chili anthracnose (*Colletotrichum* spp) in SNNP, Oromia and Amhara regions; (ii) determine whether severity could be predicted reliably from disease incidence data; and (iii) determine the effects of sampling for incidence on the precision of estimates of severity.

2. Material and Methods

2.1 Study Area

The study had been conducted in southern Ethiopia namely, Alaba (at 7.317574 latitude, 38.1042 longitude, with altitude of and 1825.77 masl), and Maraqo (at 8.024675 latitude, 38.32799 longitude, and with altitude of 2120.24 masl). The area is known for high prevalence of anthracnose disease. The plants were irrigated and cropping practices consisted of weeding and application of fungicides against anthracnose was carried out.

2.2 Assessment of Chili anthracnose incidence and severity in different locations

Two districts, viz. Alaba and Maraqo from SNNP region, Ethiopia, were assessed for the analysis. Assessments were carried out between June-August, 2013 and November- January, 2014 using 20 genotypes of the known pepper types in the country. These included Melka zala, Maraqo fana, Melka shote, Weldele, Bako local, Oda haro, Dube medium, Dube short and Gojeb local from Melkassa Agricultural Research Center (MARC). They were planted using a 70X30 inter and intra-raw spacing. They were replicated thrice in randomized block design. Two central plants were selected at random from each plot for the assessment and only the leaves of the top 2 whorls were assessed. They were visually classified on a scale of one to six, respectively for 0%, 0-20%, 21-40% 41 - 60%, 61 - 80% and 81 - 100% of the leaf area infected for computation of S. When there was complete defoliation of leaves, it was considered to be 100% infected [13].

To estimate "*I*" , the total number of leaves and the total number of diseased leaves in the 2 selected plants were recorded. Assessments were made in June-August, 2013 and November- January, 2014 about 2 weeks after, the rain had started. Disease incidence was calculated by dividing the number of infected leaves by the total number of leaves and expressed as a percentage. For the estimation of S the sum of percentage area damaged by the pathogen was divided by the total number of leaves which included both infected and non-infected.

Spearman's Rank Correlation was employed to determine as to what extent the ratio between the index of resistance and susceptibility of different clones corresponded in different seasons and different locations In respect of each of the indices of incidence and severity. Two locations, Alaba where the incidence was generally low and Maraqo where the incidence was generally high were selected. Data obtained from these two locations in two seasons viz. June-August, 2013; which had low incidence and November-January, 2014 which had high incidence were considered for analysis. The selection of locations and seasons were made in order to have a better contrast of the computed ratio.

2.3 Relationship between Incidence and severity

For determination of the relationship between I and S of the disease, data was considered from 10 resistant clones and 10 susceptible clones of Melka zala, Maraqo fana, Melka shote, Weldele, Bako local, Oda haro, Dube medium, Dube short and Gojeb from each of the two locations, Alaba and Maraqo and in two different seasons, June-August, 2013 and November-January, 2014. The regression analysis was carried out by using [14] the linear regression model S= a+bi where S=disease severity, I = disease incidence and a and b = regression parameters.

3. Results

3.1 Models on incidence-severity for chili anthracnose disease Determination

A highly significant relationship between incidence and severity of *Colletotrichum* spp was observed for all data sets at each location in each year. Despite the variation in severity at a given incidence, the relationship was fairly consistent among data sets. The model based on *log ln*-transformation of incidence and severity (equation : y=a+bx) performed consistently well on all data sets, explaining between 15.2 and 98% of the variation in severity on a *log ln* scale. The squared correlation between *S* and predicted *S* was between 0.5 and 0.92. As expected, severity was estimated more precisely at lower incidence values than at higher values, based on the width of the severity prediction interval. It should be noted that a significant relationship does not necessarily mean that precision is high enough (e.g., that the prediction interval is narrow enough) for a model to be used for predictions, since achieved significance level is highly influenced by number of observations.

In this study, severity described the percentage of necroticised leaf area while incidence reflected the percentage of diseased leaves out of the total evaluated [4, 16]. Later in each crop season, anthracnose incidence on the fruits was also assessed as percentage of symptomatic immature fruits/panicle/plant. Disease scores were initially processed to return plant mean scores [12].

Regression analysis of incidence and severity from untransformed data were performed using SAS [15] package for windows. Variables means over date and treatment were computed to fit a linear function [16]. Incidence was the response variant and severity the explanatory [4,16]. Furthermore, leaf severity and incidence were used as explanatory to the incidence on pods. Daily rainfall data were obtained from the closest district directorate of agriculture of each site. Weekly sums were computed and graphically represented for each location.

The relationship between incidence and severity on the chili leaf anthracnose pathosystem as consistently best characterized by the restricted exponential function (P<0.001): $s = a + ix$ across locations, crop seasons, and chili genotype (Table 2). In this function, '*I'* stands for incidence, '*S*' for severity, *b* for intercept and *a* stands for constant.

3.2 The incidence-severity relationships across locations on chili anthracnose disease

A negative correlation between chili anthracnose disease incidence and severity with locations was observed. In 2013 at Alaba site, the relationship between disease incidence and severity could be expressed by the equation Y= -0.762X + 30.606 (R^2 =0.0367), where X = incidence and Y = disease severity (Figure 1a).

Here, the R^2, value indicates that the contribution of locations was 3.67% on the incidence of chili anthracnose of chili. On the other hand, at Alaba in 2014, the relationship between disease severity and incidence could be expressed by the equation Y= -0.0641X + 30.714(R^2 =0.0124), where X = incidence and Y = disease severity. Here, the R value indicates that the contribution of incidence was 1.24% on the severity of chili anthracnose of chili (Figure 1b).

A negative correlation between chili anthracnose disease incidence and severity with locations was observed. In 2013 at Maraqo site, the relationship between disease incidence and severity could be expressed by the equation Y= -0.0906X + 36.777 (R^2 =0.0196), where X = incidence and Y = disease severity (Figure 2c).

Here, the R^2, value indicates that the contribution of locations was 6.92% on the incidence of chili anthracnose of chili. On the other hand, at Maraqo in 2014, the relationship between disease severity and incidence could be expressed by the equation Y= -0.0904X + 31.357(R^2 =0.0148), where X = incidence and Y = disease severity. Here, the R value indicates that the contribution of incidence was 1.3% on the severity of chili anthracnose of chili (Figure 2d).

3.3 ln incidence-severity relationships on chili anthracnose disease

A negative correlation between chili anthracnose disease ln incidence and ln severity with locations was observed. In 2013 at Alaba site, the relationship between disease ln incidence and ln severity could be expressed by the equation Y= -0.1075X + 3.6931 (R^2 =0.0692), where X = incidence and Y = disease ln severity (Figure 2a).

Here, the R^2, value indicates that the contribution of locations was 6.92% on the ln incidence of chili anthracnose of chili. On the other hand, at Alaba in 2014, the relationship between disease ln severity and incidence could be expressed by the equation Y= -0.0685X + 3.5612(R^2 =0.0111), where X = ln incidence and Y = disease ln severity. Here, the R value indicates that the contribution of incidence was 1.11% on the severity of chili anthracnose of chili (Figure 2b).

A negative correlation between chili anthracnose disease ln incidence and ln severity with locations was observed. In 2013 at Maraqo site, the relationship between disease ln incidence and ln severity could be expressed by the equation Y= -0.1061X + 3.8709 (R^2 =0.0219), where X = incidence and Y = disease ln severity (Figure 2c).

Here, the R^2, value indicates that the contribution of locations was 6.92% on the ln incidence of chili anthracnose of chili. On the other hand, at Maraqo in 2014, the relationship between disease ln severity and incidence could be expressed by the equation Y= -0.1055X + 3.6851(R^2 =0.013), where X = ln incidence and Y = disease ln severity. Here, the R value indicates that the contribution of incidence was 1.3% on the severity of chili anthracnose of chili (Figure 2d).

3.4. The Temporal, pooled incidence-severity relationships on chili anthracnose disease

In 2013, A positive correlation between chili anthracnose disease incidence and severity with seasons was observed. The relationship between disease incidence and seasons could be expressed by the equation Y= 0.3142X + 3.374 (R^2 = 0.1546), where X = seasons and Y = disease incidence. Here, the R value indicates that the contribution of seasons was 15.46% on the incidence of chili anthracnose of chili (Figure 3). On the other hand, the relationship between disease severity and seasons could be expressed by the equation Y= 0.0139X + 3.5407 (R^2 =0.2016), where X = seasons and Y = disease severity. Here, the R^2 value indicates that the contribution of seasons was 20.16% on the severity of chili anthracnose of chili (Figure 3).

In 2014, a positive correlation between chili anthracnose disease incidence and severity with seasons was observed. The relationship between disease incidence and seasons could be expressed by the equation Y= 0.5035X + 2.103 (R^2 = 0.3938), where X = seasons and Y = disease incidence. Here, the R value indicates that the contribution of seasons was 39.38% on the incidence of chili anthracnose of chili (Figure 3b). On the other hand, the relationship between disease severity and seasons could be expressed by the equation Y= 0.0015X + 3.2546 (R^2 =0.021), where X = seasons and Y = disease severity. Here, the R^2 value indicates that the contribution of seasons was 21.00% on the severity of chili anthracnose of chili (Figure 3b).

3.5. The Temporal, pooled incidence-severity relationships on chili anthracnose disease

In Maraqo, a positive correlation between chili anthracnose disease severity with seasons was observed. The temporal, pooled relationship between disease locations could be expressed by the equation Y= 0.0293X + 3.0032 (R^2 = 0.9459), where X = seasons and Y = disease severity.

Here, the R value indicates that the contribution of seasons was 94.59% on the severity of chili anthracnose of chili (Figure 4a). On the other hand, in Alaba, the relationship between disease severity and seasons could be expressed by the equation Y= 0.0282X + 3.0955 (R^2 =0.944), where X = location and Y = disease severity. Here, the R^2 value indicates that the contribution of seasons was 94.44% on the severity of chili anthracnose of chili (Figure 4a).

Furthermore a positive correlation between chili anthracnose disease incidences with seasons was observed. The relationship between disease incidence and seasons could be expressed by the equation Y= 0.0665X + 2.8291 (R^2 = 0.8246), where X = seasons and Y = disease incidence. Here, the R value indicates that the contribution of seasons was 82.46% on the incidence of chili anthracnose of chili (Figure 4b). On the other hand, the relationship between disease severity and locations could be expressed by the equation Y= 0.0396X + 3.233 (R^2 = 0.866), where X = location and Y = disease incidence. Here, the R^2 value indicates that the contribution of seasons was 86.6% on the incidence of chili anthracnose of chili (Figure 4b).

4. Discussions

In this study, the relationship between incidence and severity on chili leaf anthracnose non-transformed data, best fitted the restricted exponential group model. This model curve was previously used by [4] on two different pathosystems [10]. Numerous publications have dealt with the incidence-severity relationship of various pathosystems [4].

Various models have been produced and their application and limitations were reviewed [4,10]. Limitations associated with practical use of incidence-severity relationships are essentially derived from their inconsistency in relations to location, season, epidemic stage, crop management systems and host genotype variations [4].

Once the model has proven robust across all these, one may opt to use the easily measured parameter (incidence) [4].

Therefore we recommend the use of leaf incidence in place of severity in genotype and season trials, describing models for economic thresholds or epidemics studies of chili leaf anthracnose. However, caution is needed since the chili leaf anthracnose severity or incidence link to the fruit anthracnose incidence/severity has not been established. This is in conformity with previous finding in Brazil where severity of anthracnose was coupled with rainfall and flushing of chili [3,4].

In the model, severity was considered as dependent variable and incidence as the independent in contrary to Uaciquete [12]. Since anthracnose is a polycyclic disease [11].

Changes in incidence over time are determined by the dynamics of severity or sources of inoculum at initial stages of epidemics [4]. By exploring the regression curve minimum and maximum limits derived from the incidence-severity relationship, the propensity of the environment for the disease epidemics across different sites, crop seasons, genotype combinations and production system had been assessed by Uaciquete [12].

Anthracnose spread was clearly associated with rainfall during the first week of July. In general, this coincided with the flushing peak for most clones involved in the trials. This in agreement with knowledge that dispersion of anthracnose inoculum is by rain splashes [2].

The relationships between pairs of incidence and severity are mathematically expressed and consistent at multiple locations or environments, data from individual sites can be pooled into a summary equation without prejudice to proper interpretation [4]. The overall means for essential coefficients such as transformed 's' and 'I' were used to generate the summary equation that explained the relationships between anthracnose incidence and severity across different environments [12]. To add up, the data indicated that very low levels of severity are associated with increased infection, which is evident in the works of Uaciquete [12].

In this model, both incidence and severity were found to increase in time. When incidence approaches a maximum of 98%, the severity is around 37%. Then, only severity continues to increase up to a maximum of 45%. This pattern of post-maximum incidence increase has been discussed by [4]. The spread of the disease may be limited because severely infected senescent leaves tend to drop off and the un-infected ones (30%) may reach maturity inhibiting fungal penetration.

The result of this study was adopted the scale developed by Alamdarloo and Aghajani [16] that had initially been used for scelerotina leaf rot.

In previous studies, chili leaf anthracnose was assessed based on whole plant scores [4] and without standardized pictorial diagrams thus making it difficult to use by other workers. The use of diagrammatic scale decreased the absolute error of disease estimations by raters in the case of chili leaf and fruit blight patho-system [17,18].

All chili genotypes, including the local varieties, grown extensively towards the end of the rainy season and reproductively when the temperature declines which was in direct conformity with the findings of Alamdarloo and Aghajani [16]. Seedlings and young tend to grow continuously [16].

Thus, when the environment is favorable, two peaks of the disease epidemic may be observed in a year [3, 4].This study was annual-crop, young-leaf-based and had the advantage of being able to estimate the epidemics accurately. The authors cannot guarantee that if this method, whatsoever, be applied in all other crops with two flushes per year.

Estimation of chili anthracnose damage through its incidence on young leaves has proven to be a more effective, faster, more accurate and user friendly method than severity scores. This is in line with Alamdarloo and Aghajani [16] who found incidence data to be simpler to collect and less subjective than severity and thus recommended for larger scale surveys.

However, special attention may be necessary when assessing chili anthracnose where other similar but distinguishable leaf diseases such as leaf blight [19, 20] and Pestalotiopsis [12] are present. Furthermore, a recent research reports by many authors [6, 21, 22, 23, 24, 25] indicates that epidemiological data analysis could be improved through multivariate regression modeling.

5. Conclusions

The results of the current study establish that by simply sampling and counting the number of diseased plants in a chili farm, it is possible to estimate anthracnose severity. An acceptable model for estimating levels of anthracnose severity based upon data from different levels of disease pressure, different chili genotypes, different season, and locations at several stages of epidemic progress was obtained. Further studies on gummosis damage to obtain models to describe economic thresholds, host genetic reactions and effectiveness of disease management practices will be facilitated by the findings presented this study.

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Appendices

Appendix 1. (Table 1) General characteristics of trial sites from which anthracnose disease incidence and severity had been collected in 2013 and 2014

Table 1

Trial Name	**Latitude**	**Longitude**	**Altitude (m)**	**Zone/city/ woreda**	**Region**	**AE Zone**	**No. of farms Assessed**
AAU, 4kilo	9.037354	38.76779	2435.84	Addis Ababa	Addis Ababa	6	0
Wonji	8.4538411	39.280399	- -	Adama	Oromiya	2	8
Adama zuria	8.5263486	39.2583293	- -	Adama	Oromiya	2	3
Arsi Negelle	7.3610886	38.668713	- -	West Arsi	Oromiya	1	3
Bure	10.708145	37.0668651	- -	East Gojam	Amhara	3	3
Mankussa	10.697988	37.176773	- -	East Gojam	Amhara	2	3
Nekemte	9.0893009	36.555386	- -	West wollega	Oromiya	1	3
Gute	9.3208484	36.671451	- -	West wollega	Oromiya	3	3
Ano	9.0928759	36.959483	- -	West wollega	Oromiya	2	1
Bako	9.1248249	37.0588169	- -	West wollega	Oromiya	2	1
Achamo	7.473552	38.4449	1900	Hadiya	SNNPR	1	5
Hossana	7.552825	37.85649	2309.44	Hadiya	SNNPR	8	11
Wolaita Sodo	6.852763	37.76414	1997.79	Wolaita	SNNPR	8	8
Humbo Tebella	6.703099	37.7751	1590.79	Wolaita	SNNPR	4	9
Halaba Nursery	7.317574	38.09376	1774.78	Alaba sp. Woreda	SNNPR	6	6
Halaba Field A	7.389356	38.1042	1825.77	Alaba sp. Woreda	SNNPR	3	19
Sankura	7.353447	38.09112	1823.63	Silti	SNNPR	5	6
Sankura	7.353447	38.09112	1823.63	Silti	SNNPR	3	3
Worabe	7.737333	38.12154	1988.49	Silti	SNNPR	2	7
Alkeso	7.848471	38.18766	2096.36	Silti	SNNPR	4	4
Menagerie	7.918454	38.23706	2306.69	Silti	SNNPR	6	5
Qibet	7.949281	38.26793	2389.2	Gurage	SNNPR	3	2
Maraqo	8.024675	38.32799	2120.24	Mareko sp. woreda,	SNNPR	3	4
Qoshe Fields	8.01513	38.53197	1872.82	Mareko sp. woreda	SNNPR	4	8
Bonosha Mazoriya	8.042378	38.49944	1840.08	Hadiya	SNNPR	3	7
TOTAL							**132**

Appendix 2. (Table 2) Regression Equations of Incidence (I) on severity(s) of anthracnose under different Environments and Different Chili Genotypes 2013-2014

Table 2

linear function		**S = a+bi**					**SE**
Location	**Germplasm**	**Year**	**a**	**b**	**R^2**	**p-value**	
Maraqo	Melka zala	2013	1.1501	0.051	0.7571	0.05834	2.444
		2014	1.8769	0.1808	0.9703	0.0216	0.5697
	Maraqo fana	2013	7.0794	0.1397	0.4399	0.0279	2.311
		2014	1.3731	0.1047	0.8465	0.0754	0.6135
	Melka shote	2013	0.8941	0.0507	0.7782	0.2618	0.7071
		2014	0.1537	0.0131	0.9862	0.0122	0.0401
	Weldele	2013	0.6403	0.0799	0.8501	0.489	0.8578
		2014	1.8655	0.0781	0.8791	0.0534	0.7414
	Bako local	2013	2.0747	0.0549	0.7982	0.0376	0.7392
		2014	0.5779	0.0231	0.6407	0.1943	0.3857
	Oda Haro	2013	0.8796	0.0349	0.9127	0.0039	0.1742
		2014	1.3667	0.0952	0.8531	0.1205	0.7312
	Dube medium	2013	2.418	0.1056	0.7637	0.0498	0.9395
		2014	9.4386	0.3419	0.9218	0.0033	1.7988
	Gojeb local	2013	0.3527	0.0391	0.9352	0.2236	0.254
		2014	9.6733	0.153	0.8613	0.0009	1.3777
	Dube short	2013	-0.1293	0.1262	0.522	0.9687	3.143
		2014	1.8032	0.0192	0.8563	0.0003	0.2047
	Local LR	2013	11.5823	0.5563	0.9882	0.0007	1.5694
		2014	0.9392	0.0889	0.632	0.606	1.7114
Alaba	Melka zala	2013	0.3115	0.0901	0.9536	0.193	0.207
		2014	1.1815	0.435	0.9403	0.3441	1.1311
	Maraqo fana	2013	0.7648	0.0683	0.8791	0.118	0.4056
		2014	1.5966	0.3444	0.9909	0.0168	0.4531
	Melka shote	2013	6.6.61	0.2967	0.628	0.308	5.8314
		2014	5.9905	0.2585	0.8663	0.07167	2.6292
	Weldele	2013	-1.6292	0.2542	0.9257	0.4168	1.8414
		2014	0.0885	0.1608	0.9666	0.9123	0.7642
	Bako local	2013	-0.2317	0.0863	0.932	0.7258	0.6245
		2014	16.492	0.3509	0.9535	0.0005	2.0771
	Oda Haro	2013	1.5668	0.0561	0.8836	0.00269	0.2827
		2014	12.355	0.2579	0.8192	0.0007	1.6826
	Dube medium	2013	1.10278	0.0664	0.7794	0.0972	0.5413
		2014	0.6895	0.3036	0.8852	0.6978	0.6895
	Gojeb local	2013	0.9766	0.0675	0.9956	0.0003	0.1132
		2014	20.859	0.3353	0.7764	0.0060	4.5665
	Dube short	2013	1.535	0.02486	0.6622	0.0209	0.4621
		2014	0.3161	0.1982	0.9543	0.7906	1.1286
	Local LR	2013	0.1543	0.0664	0.6178	0.9135	1.351
		2014	0.2951	0.2132	0.8887	0.8857	1.9517
Overall mean			**3.0878**	**0.1567**	**0.836**	**0.244**	**3.088**
Alaba Mean			**3.391**	**0.1967**	**0.863**	**0.317**	**1.3958**
Maraqo Mean			**2.8005**	**0.1168**	**0.809**	**0.1664**	**1.006**

= Regression equation of incidence applied for each location: s=a+bi, SE= Standard Error of observation, R= coefficient of determination, b= incidence, a= constant.*multiply, For all locations p***<0.001

Appendix 3. (Fig. 1) Relationship between severity and incidence of chili anthracnose (*Colletotrichum* spp) in 2013 (a & b) and 2014 (c & d) cropping seasons.

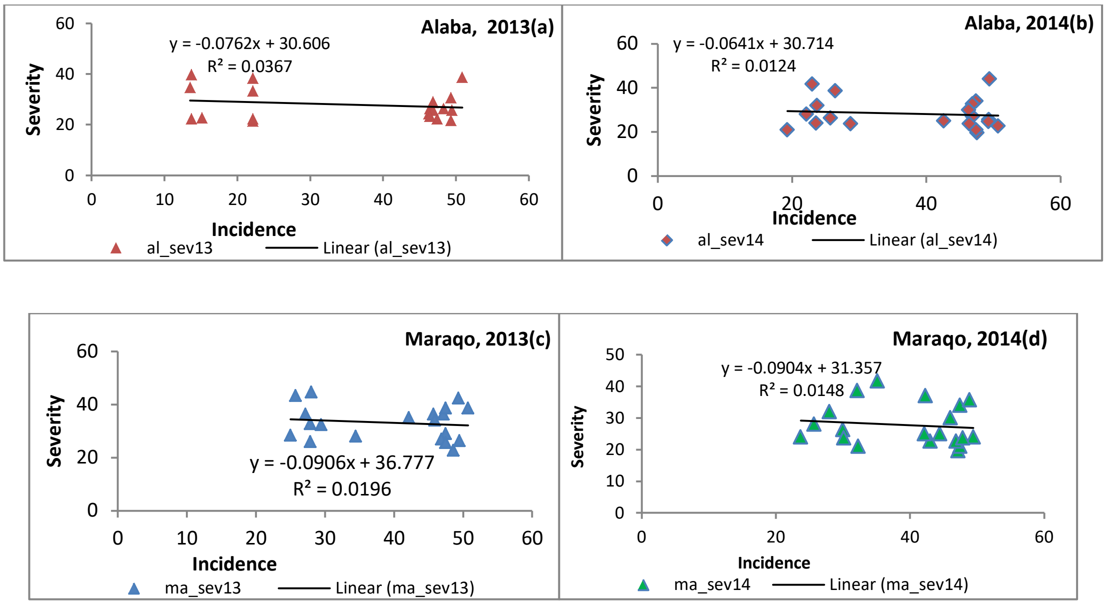

Figure 1

Appendix 4. (Figure 2). Relationship between severity (a and b) and incidence (c and d) of chili anthracnose (*Colletotrichum* spp) at Alaba and Maraqo with log (ln) transformation.

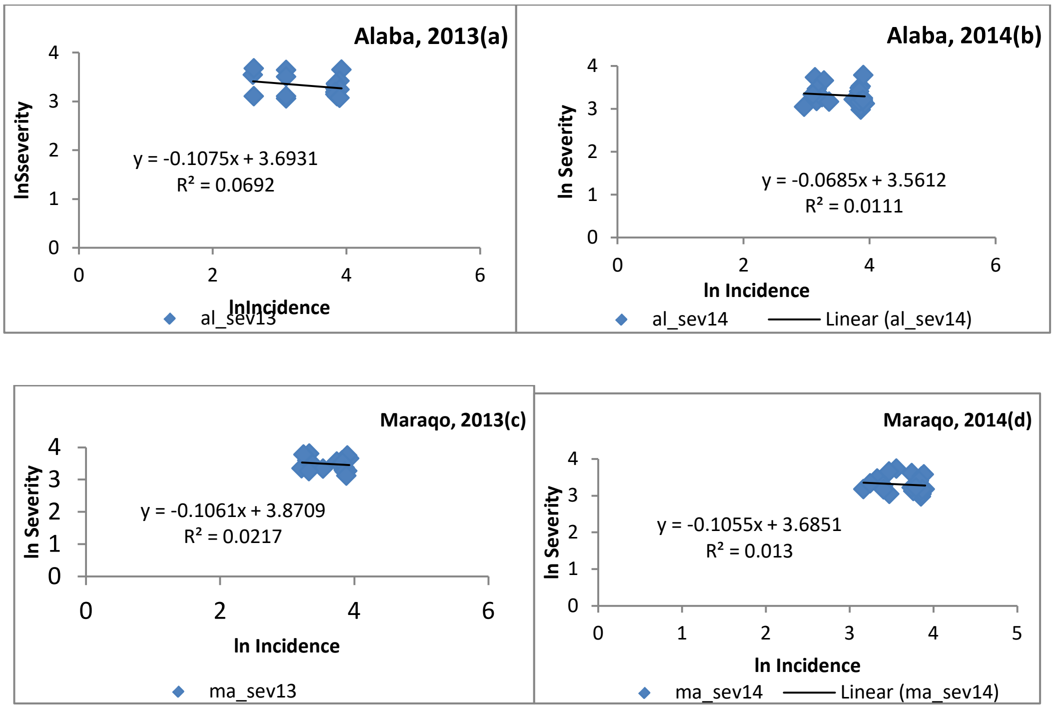

Figure 2

Appendix 5: Figure 3 (upper) and Figure (lower) on Trends of severity

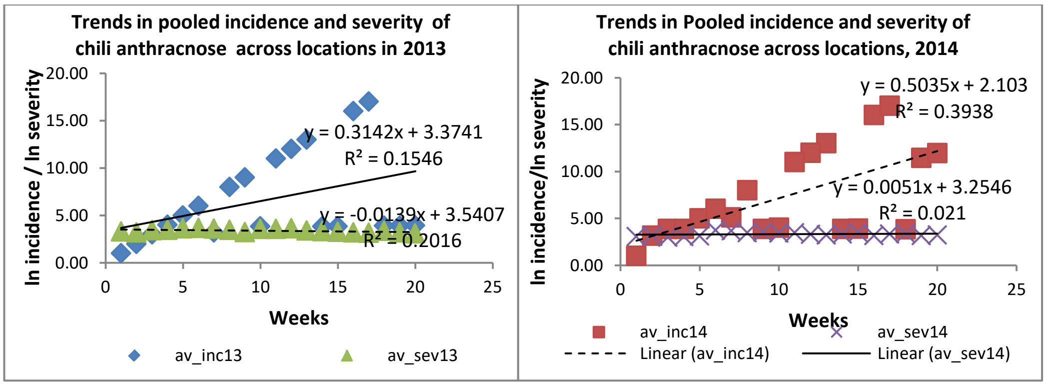

Figure 3: Trends in Pooled incidence (solid line) and severity (broken line) of chili anthracnose (*Colletotrichum* spp) across locations in 2013(left) and 2014(Right)

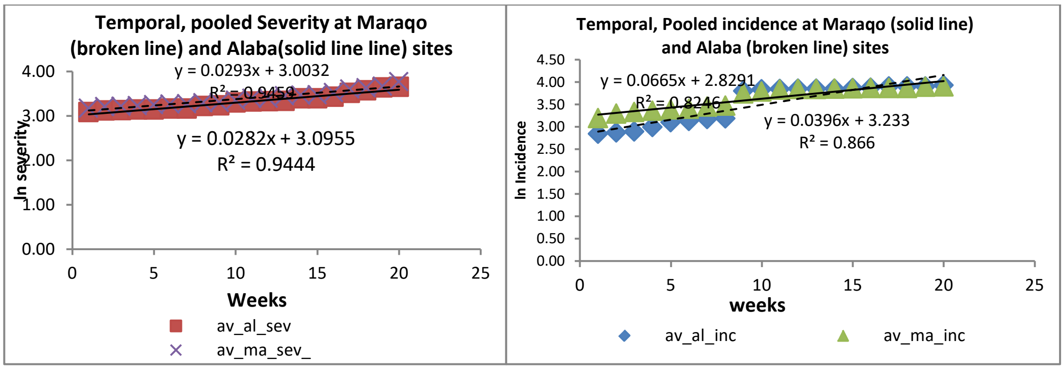

Figure 4: Temporal, pooled severity (left) and incidence (right) of chili anthracnose (*Colletotrichum* spp) in Maraqo and Alaba Sites