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Evaluation of yield decrease in common beans due to anthracnose (*Colletotrichum lindemuthianum*) below sub-temperate environment of Northwestern of Rwanda[#]

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ARTICLE INFO	ABSTRACT
	The research was conducted in the year of 2021-2022 in Burera and Musanze District in Northern province as well as Rubavu District in Western Province with the aim of assessing the yield loss in common beans due to anthracnose by using four cultivars with various levels of resistance in field conditions in environment of Northwestern of Rwanda. Randomized complete block design as experiment design was used in this study where each selected cultivar was grown and the yield loss caused by anthracnose was assessed. A level of significance of P<0.05 . In field trials, on the particularly susceptible cultivar Gikundiro 2 particulary showed the maximum harm in terms of incidence and severity in both infection circumstances. The severity of pod infection ranging from 3-9 (0-) resulted in reduction in quantity of seeds which contain a pod ranging from 10.52 % -57.76 % and the loss in weight of seeds per pods ranging from 21.93 % - 68.77 %, both demonstrated a direct impact on seed yield. However, determinate cultivars showed a greater drop in yield (58.5%) than indeterminate cultivars (10.52%) although both were sensitive, based on this research, anthracnose causes economic yield loss on variety Gikundiro 2 and Vuzimpundu.

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Introduction

Beans are one of the main crops grown in Rwanda where they are grown in the mid hills of 900-1300 meters above sea level and high hills of 1800-3000 meters above sea level. The total production area of beans is 2037 ha with 3.5 tones /ha grain yield in subtropical to temperate agro-climatic conditions (Musana et al 2020). Common beans are often grown during the growing seasons (September 2020 for season A, February and 2021 for season B) and the humid atmosphere makes the crop vulnerable to fungal, bacterial and viral infections. *Colletotrichum lindemuthianum* (Sacc. and Magnus) Lams-Scrib causes anthracnose of beans which is the destructive diseases in tropical and subtropical environments especially under cold and humid settings. The crop is vulnerable to pathogen attack from seedling to maturity depending on the presence of favorable climatic conditions for disease initiation and development (Erdinc et al, 2017).

In the northwest of Rwanda, bean anthracnose is a common occurrence with a wide pathogenic variety and Kiryumukwe (RWV 1129) cultivar is susceptible to any race of the pathogen. In susceptible kinds, the disease causes yield and quality losses with yield losses as high as 95% in some cases. Even though various elements of bean anthracnose have been thoroughly investigated, there is little information in the literature stated in the estimation of yield loss as the essential element to consider when conducting inventory on crop production, policies of crop insurance, deployment of gene as well as quarantine variety (Urinzwenimana et al, 2017). Under epidemic conditions, the fungus' seed-borne nature can have a devastating effect on both quantity and quality of output.

This research presents the results of loss estimation in kidney bean cultivars with differential resistance to bean anthracnose as well as the impact of background

contamination (an infection that begins outside the field) on the crop quality and quantity (Imran et al, 2021).

Materials and Methods

Area for research

The study took place in Rwanda, Gicumbi and Burera Districts of the Northern province and Rubavu District of the western province, The last to districts share a border with Uganda to the north, while Rubavu District shares border with the Democratic Republic of Congo on the west. The area has an altitude averaged of 1,400 m a.s.l with 1°22' 51.6" south latitude as well as 30° 17' 07" east longitude. The rain per year is between 800 and 1000 millimeters while the average of temperature per year is between 25.3°C -27°C. The soils in the higher land region are humid ferrasols while that of lower region is vertisols with the pH of 6.3 (Mohammed H.et al, 2015).

Experimental Design

Soil analysis revealed that the experimental soil had medium nitrogen and phosphorus concentration as well as high potassium content before field preparation. Before planting, necessary levels of nitrogen and phosphorous (20 kg and 60 kg /ha respectively) were applied (Mojid et al, 2021). During the growing season 30 plots of 2 x 1.5 m^2 each were planted with four bean cultivars: Vuzimpundu (RWV 3316) (resistant), Mpanguhe (RWV 3317) (moderately resistant), Gikundiro 2 (MAC 49) (highly susceptible) and Kiryumukwe (RWV 1129) (susceptible) in Randomized complete block design (RBD) with 3 replications. To reduce inter-plots interference, guard plots of 1 x 1 m^2 were used. Carbendazim was sprayed three times 0.1 percent at different phases of plant growth in the check plots to keep them disease-free it means control plots along with a seed treatment of 2.5 gm per kg of seed. Because it proved resistant to 103 and 935 races in field settings, the Vuzimpundu (RWV 3316) cultivar was preserved as an overall check. The experiment was repeated for two seasons but because the second year was not an epidemic year, only one-year's data was used to determine yield losses.

The progression of the disease through time

The severity of anthracnose was recorded at 15-day intervals from the arrival of 1st signs of disease through the crop maturity in cultivars and treatments to study disease progression over time. The infection rate 'r' was determined using Vander Plank's standard equation (1963) and I calculated the AUDPC with referring to Shaner and Finney's method (1977) (Alves et al, 2016).

Estimation of yield loss

Infected seeds of the susceptible cultivars Gikundiro 2 (MAC 49), Kiryumukwe (RWV 1129), and the moderately resistant cultivar Mpanguhe (RWV 3317) were utilized for investigating the seed-borne inoculum effect on disease development and yield of common beans, while healthy seeds of these varieties were sown to investigate the role of background contamination (external source of inoculum). Anthracnose was introduced to the healthy seed plots by planting two border rows of sensitive cultivars). Gikundiro 2 (MAC 49) was infected with a combination of races found in the Gicumbi District area at the primary leaf stage and second trifoliate leaf stage (103 and 935) to plants were sprayed three times with Carbendazim at different stages of plant growth (35 days after planting, pod initiation, and pod development) as well as a seed treatment in control plots of each type. 2.5 grams of seed per kilogram data on disease incidence and severity were collected every 15 days from the onset of symptoms until the crop reached maturity. The plants were monitored for symptom development on a regular basis and 25 of them were labeled to keep track of disease severity and yield. At harvest, the quantity (numbers) of pods in each plant as well as the quantity (numbers) of seed in each plant were counted. After the seeds were sun-dried, the yields of various treatments were calculated to calculate yield loss as a percent yield loss in various cultivars, and the following formula was used:

$$\text{Percent yield loss} = 100 \times (YCP-YDP)/YCP$$

Where YCP stands for yield in the control plot and YDP stands for yield in the diseased plot. (Nirmala et al, 2015)

On a randomly selected pod, a 0-9 point scale from diseased to healthy was used to investigate the relationship between disease severity and yield, and 25 pods/ response type/ replication were used to quantify disease severity and yield. For yield comparison, healthy pods from the control plot were chosen, the weight of the seeds per pod and the number of seeds per pod were also verified.

Results and Discussion

Anthracnose development on various cultivars

On four bean cultivars with variable resistance, the progression of anthracnose originating from seed-borne infection (infected seed crop) and background contamination (external inoculum) revealed that disease incidence and severity were significantly higher in the highly susceptible cultivar Gikundiro 2 (MAC 49) in the crop raised from infected seed. (Fig1&2) (Binyam Tsedaley, 2015). Due to seed-borne infection, the cultivar Gikundiro 2 (MAC 49) had the highest terminal disease severity (79.48 percent), followed by Kiryumukwe (RWV 1129) (26.23 percent), and Mpanguhe (RWV 3317) (3.74 percent). Similarly, significant changes in disease incidence among types were discovered. No disease was recorded in cultivar Vuzimpundu (RWV 3316) (Highly resistant) which was planted as an overall

check. The disease initiated about two weeks late (July 2021) in the crop having background contamination as compared to the crop raised from infected seed (Muhammad et al,2018).

Seed-borne infection and background contamination were statistically equal in terms of terminal illness severity and apparent rate of infection. However, in seed-borne infection, AUDPC was much greater, which could be attributable to the fact that disease began late (2 weeks) in background contamination. (Chang et al, 2020). Table 1 shows the AUDPC, terminal severity of disease and apparent infection rate 'r' for several cultivars. For AUDPC, there were very significant variations among the extremely susceptible, susceptible and moderately resistant genotypes between among treatments. In both the crops receiving.
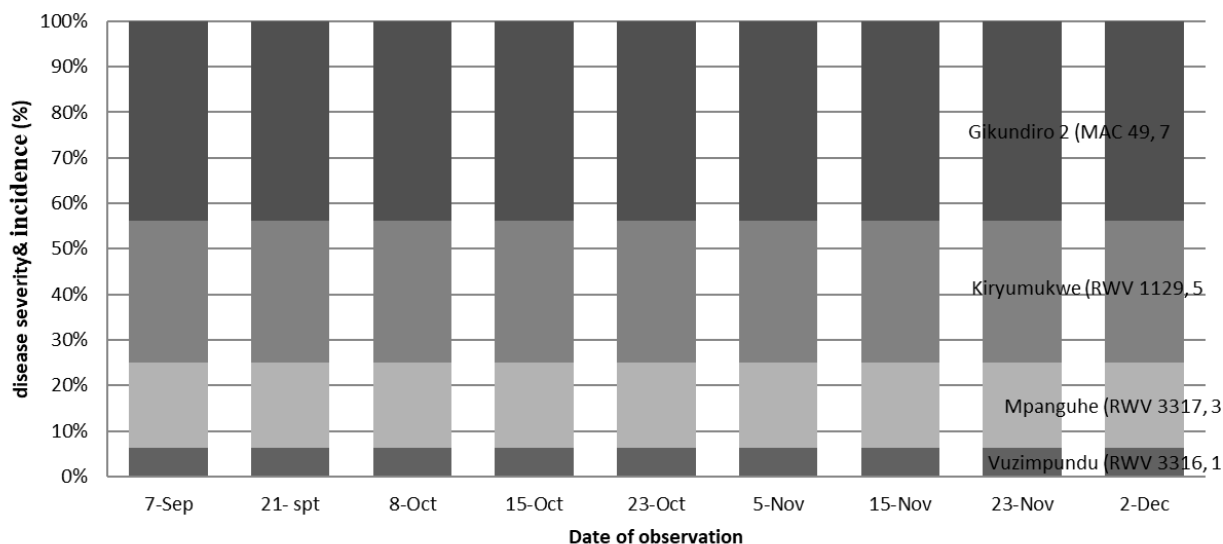
Figure 1. Bean anthracnose develops on common bean varieties as a result of a seed-borne infection
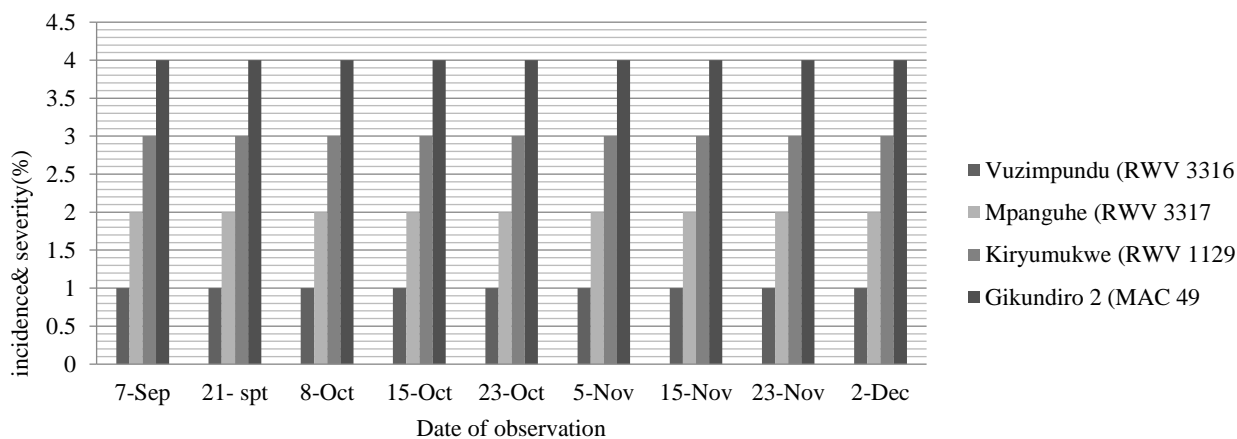

Figure 2. Enlargement of bean anthracnose on common bean cultivars initiating from background contamination

inoculum from seed-borne infection and background contamination, the AUDPC was highest in Gikundiro 2 (MAC 49) (2672.69) and lowest in Mpanguhe (RWV 3317) (327.64). Observations on the severity of terminal disease and the apparent rate of infection showed essentially identical trends in different kinds. The results demonstrated that the terminal disease severity of the extremely sensitive, susceptible and moderately resistant cultivars differed significantly (Buerstmay, 2019). There were no significant differences in terminal disease severity or infection rate between crops with a seed-borne infection and those with background contamination while the latter had lower values. The findings demonstrated that the apparent rate of infection differed significantly amongst the cultivars (Krishna et al, 2021)

Estimation of productivity loss

Table 2 shows the impact of seed-borne infection and background contamination on yield parameters of various varieties. Amount of pod in each plant and grains per pod per plant decreased by 40% for extremely sensitive (Gikundiro 2 (MAC 49)) cultivar, but was non-significant in susceptible (Kiryumukwe (RWV 1129)) and moderately

resistant (Mpanguhe (RWV 3317) cultivar. Cultivar Gikundiro 2 (MAC 49) showed maximum reduction in the amount of pods per plant and the amount of grains per pod in each plant in both the crops raised from infected seed and under background contamination. However, the amount of pod per plant and amount of seed per pod per plant were lower (2.4%) in the plants having the seed-borne infection. In Bavistin sprayed plants of all cultivars, the total number of pods per plant and the amount seed per pod per plant were at their highest (Asif et al, 2021).

The quantity of pod per plant and quantity of seed per pod per plant decreased most as a result of seed-borne infection in cultivar Gikundiro 2 (MAC 49). (41.90 % and 52.24 %, respectively). Background contamination caused a similar drop in Gikundiro 2 (MAC 49). (37.44 % and 49.13 %). The production potential of the cultivars differed significantly, with the susceptible cultivar (Kiryumukwe (RWV 1129)) producing the highest yield when anthracnose was managed. The experimental results show that the seeds yield for all varieties were highest in check plots of 111.6%.

Table 1. Proportional account of anthracnose initiating from seed-borne contamination and background contamination in different cultivars of common bean under natural epiphytotic conditions*

Cultivars **	AUDPC			Disease severity (%)			Rate of infection (per unit per day)		
	ISS	BC	Mean	ISS	BC	Mean	ISS	BC	Mean
Vuzimpundu (RWV 3316)=R	45	56	50.5	0	1.9	0.95	0	0.011	0.006
Mpanguhe (RWV 3317)=MR	345	178	261.5	3.8	2.8	3.3	0.02	0.023	0.047
Kiryumukwe (RWV 1129)=S	967	643	805	28.5	26.3	27.4	0.04	0.053	0.029
Gikundiro2 (MAC 49) =HS	2652	1764	2208	78.3	73.9	76.1	0.08	0.078	0.079
Mean	1002.25	660.25		27.65	26.22		0.035	0.041	
CD(P=0.05)	Cultivar:105.59 Treatments:86.46 CVx Treat.Interactions:149.81			Cultivar:105.59 Treatments:86.46 CVx Treat.Interactions:149.81			Cultivar:105.59 Treatments:86.46 CVx Treat.Interactions:149.81		

ISS: The infection spread through seeds; BC: Background contamination; *Average of three replication; ** HS stands for Highly susceptible; S stands for Susceptibility; MR stands for Moderate resistants; R stands for Resistants, AUDPC stands for the area under the disease progress curve

Table 2.A, B, C: Effect of yield parameters of different varieties of common beans under field condition.

Cultivar **	A. Number of pods per plant			
	Infection spread through seeds	Background contamination	Treated#	Mean
Vuzimpundu (RWV 3316) =R	2.5	9	8.6	6.7
Mpanguhe (RWV 3317) =MR	17.6	13.2	15.3	15.4
Kiryumukwe (RWV 1129) =S	37.4	38.3	35.3	37
Gikundiro (MAC 49) =HS	9.8	18.4	17.4	15.2
Mean	16.8	19.7	19.2	3.6
CD (P=0.0 5)	Cultivar: 105.59 Treatments: 86.46 CVx Treat.Interactions:149.81			
	B. Number of seeds per pods/plants			
Vuzimpundu (RWV 3316) =R	1.4	1.9	1.3	1.5
Mpanguhe (RWV 3317) =MR	2.1	6.3	2.4	3.6
Kiryumukwe (RWV 1129) =S	5.3	5.5	6.4	5.7
Gikundiro (MAC 49) =HS	5.6	3.1	5.1	4.6
Mean	3.6	4.2	3.8	0
CD (P=0.0 5)	Cultivar:105.59 Treatments:86.46 CVx Treat.Interactions:149.81			
	C. Yield per plant(g)			
Vuzimpundu (RWV 3316) =R	11.8	23.1	24.2	19.7
Mpanguhe (RWV 3317) =MR	35.3	32.4	35.6	34.4
Kiryumukwe (RWV 1129) =S	96.4	97.4	112.6	105
Gikundiro (MAC 49) =HS	13.2	39.2	40.8	40
Mean	39.2	48	53.3	0
CD (P=0.0 5)	Cultivar:105.59 Treatments:86.46 CVx Treat. Interactions: 149.81			

Note: R stands for Resistant, MR stands for moderate resistant, S stands for susceptible and HR stands for highly susceptible.

Among the very sensitive, susceptible and moderately resistant genotypes, there were highly significant differences in yield and yield loss. The yield losses were severe for the extremely vulnerable and susceptible bean varieties, but not for the moderately resistant ones. The yield loss was greatest in extremely sensitive and susceptible bean cultivars, with the largest yield drop of 70.59 percent in Gikundiro 2 (MAC 49) and the lowest yield reduction of 2.81 percent in moderately resistant (Mpanguhe (RWV 3317)).

A similar trend of yield reduction was seen in the crop grown in the presence of background pollution with the greatest reduction in cv. Gikundiro 2 (MAC 49). (67.61 %).

Although statistically equal yield reduction owing to seed-borne infection was larger in different cultivars than background contamination (Chang et al, 2020).

Relationship of disease severity levels with yield

The data on the impact of pod infection in the productivity of the highly susceptible bean cultivar (Gikundiro 2 (MAC 49)) in terms of the quantity of seeds per pod as well the weight of seed per pod revealed significant differences in the quantity of grains per pod and the weight of grains per pod in pods of various severity grades, with the highest amount of grains per pod and weight of grains per pod in pods of zero severity, which

served as the control. The number of seeds per pod was reduced by the most, 57.76 percent, in pods graded 9, followed by 52.59 percent in pods graded 7. Similarly, pods with a severity grade of 9 exhibited the greatest reductions in seed weight/pod (68.77%) while pods with a severity grade of 1 showed the least. There were no significant differences between pods graded 1 and healthy pods (control) (Conner et al, 2021).

Significance differences at P<0.01 were identified in both disease severity as well as percent reduction in the amount of grains per pod (r=0.97) , the climate in which the current experiments were conducted was sub-temperate with moderate to high and frequent rainfall throughout the season. Anthracnose epidemics have been found to thrive in this type of climate (Salihu et al, 2019).

Bean anthracnose development and losses can be far more severe in temperate than in tropical zones. The disease has resurfaced in all of the district's prospective bean-growing areas resulting in significant yield decreases in vulnerable cultivars. Disease levels differed significantly between resistant and susceptible cultivars as well as between sprayed and unsprayed plots. Although the Kiryumukwe (RWV 1129) cultivar was susceptible the disease severity was significantly lower than that of the highly susceptible Gikundiro 2 (MAC 49) (bush type). This could be attributed to the Local variety's trailing type growth habit which may have resulted in infection avoidance and slow vertical spread of the pathogen. In the moderately resistant cultivar (Mpanguhe (RWV 3)) there were no significance difference in disease severity between sprayed and unsprayed plots (Gaudencia J. Kiptoo et al, 2020).

Bean anthracnose has a significant impact on bean production due to poor seed germination, seedling vigor, increased plant death, and low yields. Seed spots and blemishes are blamed for marketing losses since they affect the quality rating and salability of the product. Because the terminal disease severity was similar in both treatments (seed-borne infection and background contamination), the non-significant differences in yield reductions per plant in different cultivars could be attributed to maximum disease severity on pods at the growth stage of the pod, which is the greatest susceptible stage in the crop for rapid and fast diseases progression (Abraham Negera and Mashilla Dejene, 2018).

Early pod infection which causes pod death and drops appears to be causing a reduction in the amount of pods per plant and weight of grains /plant insensitive bean varieties resulting in a loss in seed yield. Depending on the situation, anthracnose-related yield losses in susceptible cultivars range from 38 to 100 percent. Because the regression equations revealed substantial correlations among severity grades, the number of seeds per pod and seed weight per pod, yield loss estimations based on severity grade on pods can be made with confidence.

The equations' validity, however, will apply to regions where crops are cultivated in epidemic conditions. Anthracnose infection caused a 43.9 percent production loss in French beans and researchers discovered that contamination of pods directly affected the grains yield; however, the magnitude of losses varied depending on severity level. Mohammed et al,(2013)investigated the anthracnose severity in beans as well as the influence of it on bean productivity and discovered that the extreme severity of 17.2 -76.6 percent bring out in the average yield loss of 67.2 percent.

Conclusion

In susceptible cultivars of common beans, both seed-borne infection and background contamination can cause nearly identical losses during epidemic years; however, losses are higher in crops where disease originates from infected seed because seed bone infection causes diseased seedling death in addition to early disease initiation in the crop. Seed yield is similarly affected by pod infection, also the scale for loss varies depending on severity of contamination. Indeterminate type varieties also have higher losses than indeterminate type types.

Acknowledgement:

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