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Rice blast disease occurrence on rice cultivars grown in high and middle altitudes agro-ecologies of Burundi

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Abstract

Rice blast caused by *Pyricularia oryzae* is the major damaging disease in nearly all rice-growing nations. Incidence and severity of rice blast disease were recorded and analyzed, in a triplicated randomized Complete Block experiment implemented in high altitude (HA) and middle altitude (MA) agro-ecologies. High significant difference between agro-ecologies (p=0.000) were observed in rice blast disease incidence and severity. High altitude region had the higher disease incidence (68.68%) and severity (77.53%), than the disease incidence (3.42%) and severity (20.74%) recorded in Middle region. Significant differences were observed between the location and cultivar for leaf blast incidence (p=0.024) and severity (p =0.030) at the booting stage. Rice blast disease incidence and severity on cultivars were statistically significantly different (p<0.05) at different growth stages, except for the severity at the dough stage in the Middle region. The incidence varied from 2.49 to 9.67% and the severity from 11.11 to 33.33% at the tilling stage; varied from 3.07 to 9.83% for incidence and severity from 11.11 to 48.155% at the booting stage and incidence varied from 0.49 to 1.68% the dough stage. In high altitude, rice blast incidence (74.12-90.89%) and severity (48.15-100%) were statistically significant respectively at the booting stage and dough stage. The Area Under the Disease Progress Curve (AUDPC) showed that the disease progress in all cultivars increased exponentially from tillering to the booting stage, but at the dough stage the disease progress in some cultivars maintained increment while plateaued others.

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Introduction

Rice (*Oryza sativa* L.) is the main staple food for more than a half of the world's population (Koide *et al*., 2009). Rice crop provides 20% of world's dietary energy supply and considered as a source of income for millions of small-holder farmers (Geoffrey *et al*., 2020). Asian countries produce most of the world's supply whereas in Africa continent, rice demand exceeds its production (Nasrin *et al*., 2015). In sub-Saharan Africa (SSA), the average rice yield remains relatively low (2.2tons/ha) compared to 3.4ton/ha global average (Norman and Kebe, 2006 cited in Geoffrey *et al*., 2020). This low yield is mainly justified by a series of biotic and abiotic diseases impacting rice production. Among those diseases, rice blast, caused by an ascomycete fungus *Pyricularia oryzae* (telomorph *Magnaporthe oryzae*; synonym *Magnaporthe grisea*) is the most devastating disease (Khan *et al*., 2016).

Pyricularia oryzae is a pathogen originated from Southeast Asia (Saleh *et al*., 2014) and has been distributed in the entire world mainly through the introduction of new genotypes and seed exchange (Ballini *et al*., 2008; McDonald and Linde, 2002). In West Africa and the largest area of African production, this pathogen is key constraint for production because of yield losses varying from 3 to 77% (Shahriar *et al*., 2020). Rice blast disease is a seedborne disease (Hubert *et al*., 2015) infecting rice crop from seedling to maturity and huge losses can be observed if it attacks seedling in seedbed and early neck blast (Fetene, 2019).

The fungus begins its infection cycle when a three-celled conidium arises on the surface of the rice leaf, and the spore attaches to the hydrophobic cuticle and germinates (Chuwa, 2016). *Pyricularia oryzae* forms an infection structure called appressorium and disease lesions occur between 72 and 96 hours after infection and sporulation occurs in moist conditions (Talbot, 2014). Rice blast disease symptoms are identified as lesions in the infected area in a circular or diamond shaped form or spindle-shaped dark spots with grey or white centers and brown (IRRI, 2014). The disease attacks all above ground parts of rice (leaves, neck, nodes, and panicles) and damages caused by the disease differs depending on the infected parts (Zhu *et al*., 2005 and Asibi *et al*., 2019). For that reason, depending of the infected parts, the disease can be called: leaf, blast, node blast and panicle blast (Webster, 2000). The pathogen inflicts serious damage in case of leaf blast and panicle blast (Seebold *et al*., 2004, Emmanuel *et al*., 2013). However, panicle blast is directly linked to rice production by reducing the quality and results in partially filled or unfilled grains (Grill *et al*., 1982 and IRRI, 2014). The disease is characterized by high genetic mutation allowing it to develop adaptive traits that improve their propagation in new environments (McDonald and Linde, 2002). Despite the efforts of rice farmers in using good cultural practices, rice blast is still one of the most devastating fungal diseases of rice fields (Miah *et al*., 2013; Asibi *et al*., 2019). Losses caused by rice blast disease can lead 70 to 80% of annual rice yield (Nasruddin and Amin, 2013; Rijal and Devkota, 2020). In Burundi, rice blast disease was first identified in 1986 on the variety Yunnan 3 in Gisha marshland in Ngozi Province (Ndikuryayo, 2015). In 1988 the disease destroyed malagashes rice cultivars at Kobero in Muyinga Province (Nzeyimana, 2015).

Rice farmers know the disease and use all the means of control at their disposal, but no added value. In addition, there is no updated information on the incidence and severity of rice blast disease under field conditions in some areas of Burundi including High (Buyenzi region) and Middle (Mosso region) altitudes zones. That's why the present study aims at determining the incidence and severity on rice cultivars preferred by rice farmers in the Buyenzi and Mosso regions. The results will allow researchers to make decisions on appropriate approaches for management of rice blast disease.

Materials and methods

Study area

The study was carried out in two agro-ecologies: High altitude (HA) in Buyenzi and Middle altitude (MA) in Mosso regions. Buyenzi region is located at an altitude of 1824m over the sea level, annual mean temperature ranging from 16 to 20°C and annual mean rainfall varying from 1200 to -1500mm. Mosso regions is located at altitude of 1260m. Over the sea level, annual temperature is between 17-25°C and average annual rainfall is 1100 -1500mm. For each site, two seasons can be distinguished in terms of rice cultivation such as dry season from June to November and wet season from December to May. Table 1 show temperature, precipitation and relative humidity when the current experiment was conducted.

Table 1. Monthly temperature, precipitation and relative humidity at High (*Buyenzi region*) and Middle (Mosso region) altitudes zones.

Month	Mosso region					Buyenzi region				
	Temperature		Mean	Precipitation (mm)	Relative humidity (%)	Temperature		Mean	Precipitation (mm)	Relative humidity (%)
	Min.	Max.				Min.	Max.			
January	28	16.3	22.1	231.6	77.7	24.8	14.5	19.7	189.5	79.6
February	28.3	16.6	22.4	164.7	77.7	25.5	14.6	20	135.5	79.3
March	28.8	15.7	22.2	184.6	74.5	25.2	14	19.6	152.4	77.8
April	28.1	16.3	22.2	159.1	77.8	24.4	14.1	19.2	244.8	82.2
May	28.2	15.3	21.8	82	75.7	14.5	14.5	14.5	132.6	79.2
June	29	13.2	21.1	0	66.5	25.7	13.2	19.5	1.7	68.5
July	28.5	12	20.2	0	62.7	25.3	12.8	19.1	0	59.4
Average	28.4	15.1	21.7	117.4	73.2	23.6	14.0	18.8	122.4	75.1

Experimental materials

Rice cultivars used were composed of 10 cultivars described in below Table.

Table 2. Description of rice cultivars used for evaluation of rice blast disease in field.

SN	Cultivar	Local name	Origin region	Date of release
1	IR77713-30-1-1-3	Vuninzara	MA	20111
2	IR79511-47-2-6-5	Gwizumwimbu	MA	2011
3	IR91028-115-2-2-2-1	Mugwiza	MA	2016
4	V46	Kigori	HA	1997
5	Landrace	Watt	HA	NA
6	V564-2-7	Kabuye (Rubabi)	HA	2002
7	V18	Umuzambiya	HA	NA
8	Landrace	Karundi	HA	NA
9	Landrace	Buname	HA	NA
10	Landrace	Rufutamadeni	HA	NA

NA: Not Applicable, HA: High Altitude, MA: Middle Altitude

Those cultivars have been chosen in the two agro-ecological zones because they are commonly grown by majority smallholder farmers. Cultivars like Mugwiza, Gwizumwimbu and Vuninzara have been chosen in the middle altitude whereas Buname, Karundi, Watt, Kigori, Rufutamadeni, V18 and Kabuye have been chosen in the high altitude.

Experimental design

The experiment was carried out at HA and MA regions using ten. Cultivars often used by rice farmers (described in Table 1). The experiment was laid in a Randomized Complete Block Design (RCBD). Each variety was planted in a plot of 11.2m² and the spacing between plants was 20cm x 20cm. The distance between plots was 1m and 2m between main plots. Each block was 25, m long and 5.6m wide. The total experimental area was 142,8m² for each block. Nurseries were established in January 2021 and transplanting was done in February 2021, three weeks after seeding.

Assessment of rice blast disease incidence and severity

Rice blast disease incidence and severity were determined from experimental trials set in HA and MA agro-ecological zones. For each location, rice blast disease incidence was recorded on leaves and panicles using the formula described by Hajano *et al.* (2011) whereas disease severity was done referring to the standard evaluation system (SES) for rice as described by IRRI (2014). Thereafter, disease severity was calculated using the formula described by Ghazanfar *et al.* (2009).

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants X 100}}{\text{Total number of plants assessed}}$$

$$\text{Disease severity (\%)} = \frac{\text{Average of disease score}}{\text{Maximum numerical value scale}} x100$$

Leaf blast was recorded twice at tilling stage and at booting stage so that panicle blast was assessed when plants were at dough stage.

Disease Severity Index (%)= $\frac{\text{nxv}}{\text{N x V}}100$ (Salimah *et al.* (2019)

Where, n: Number of leaves / panicles with disease symptoms

v: Score of affected leaves / panicles

N: Total number of plants observed

V: Maximum numerical value of symptoms

The Area Under Disease Progress Curve (AUDPC) was calculated as described by Mohapatra *et al.* (2008) and Pasha *et al.* (2013).

AUDPC= ☐ [(0.5) (Yi+1+Yi)(Ti+1-Ti)] Where, Y= disease severity at time i

T=time (days) of the assessment

Table 3. Standard Evaluation System of rice blast disease on leaf.

Code	Description of types of lesion
0	No lesions observed
1	Small, brown, specks of pinpoint size or larger brown specks without sporulation center
3	Small, roundish to slightly elongated, necrotic, sporulation spots, about 1-2mm in diameter with a distinct brown margin or yellow halo;
5	Narrow or slightly elliptical lesions,1-2mm in breadth, more than 3mm long with a brown margin
7	Broad spindle-shaped lesion with yellow, brown or purple margin;
9	Rapidly coalescing small, whitish, grayish, or bluish lesions without distinct margins

Source IRRI (2014)

Table 4. Standard Evaluation System of rice blast disease on panicle.

Code	Description of types of lesion
0	No visible lesions or observed lesions on only a few pedicels
1	Lesions on several pedicels or secondary branches
3	Lesions on few primary branches or the middle part of panicle axis
5	Lesions partially around the base(node) or the uppermost internode or the lower part of panicle axis near the base
7	Lesions completely around panicle base or uppermost internode or panicle axis near base with more than 30% of filled grains
9	Lesions completely around panicle base or uppermost internode or the panicle axis near the base with less than 30% of filled grains

Source IRRI (2014).

Data analysis

Data analysis on rice blast disease incidence and severity were subjected to the analysis of variance (ANOVA), using (SPSS) software. Statistical model: $Yijk = \mu + \alpha i + \eta k\ i + \beta j + \alpha\beta\ ij + \varepsilon k$ Where, μ: Grand mean, αi: mean effect of location, $\eta k\ i$: Error plot, βj: Mean effect of cultivars, $\alpha\beta\ ij$: Interaction between Location and cultivars, $\varepsilon k\ \ i$: Error split plot. Comparison of mean for rice blast disease incidence and severity were performed using Duncan's Multiple Range Test (DMRT) at 5% confidence level. In the model, rice blast disease incidence and severity were the dependent variables and location and Cultivars the independent variables.

Results

Rice blast disease incidence and severity

Results on the effects of the locations and cultivars on rice blast disease incidence and severity are presented in Table 4. Table 4 shows that the effect of location was statistically significant (p=0.000). Effects due to variety were not significant (p>0.05). Similarly, effects due to interaction between site and variety were not significant except for leaf blast incidence (p=0.024 and severity (p=0.030) at booting stage.

Table 5. ANOVA for incidence and severity of rice blast disease at different growth stage in two agro-ecologies of Burundi.

Growth Stage	Source	Incidence		Severity	
		F	Sig.	F	Sig.
Tillering	Location	106.963	0.000	106.963	0.000
	Cultivar	0.239	0.986	0.239	0.986
	Location* Cultivar	1.037	0.429	10.037	0.429
Booting	Location	2673.630	0.000	160.026	0.000
	Cultivar	0.914	0.523	0.538	0.838
	Location*Cultivar	2.470	0.024	20.362	0.030
Dough	Location	50.948	0.000	102.273	0.000
	Cultivar	0.708	0.698	1.295	0.270
	Location*Cultivar	0.725	0.683	1.182	0.333

Severe leaves and panicles rice blast disease was recorded in Buyenzi region, while it was low in Mosso region (Fig. 1).

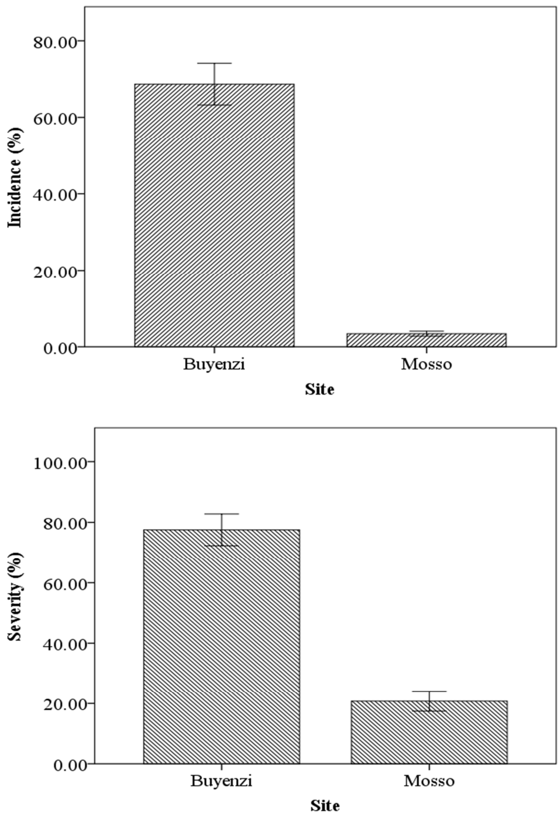

Fig. 1. Incidence and severity of rice blast disease in two agro-ecologies of Burundi.

The highest rice blast incidence (68.68%) was observed in HA, while the lowest incidence (3.42%) was registered. Highest rice blast disease severity (77.53%) was recorded in H EAZ, while it was low (20.74%) in MA.

Effects of rice blast disease incidence and severity of ten rice cultivars

A high incidence of rice blast was observed on the Karundi variety (80.98%) in HA, while a low incidence of rice blast disease was observed on the Watt variety (6.84%) in MA (Fig. 2). Similarly, a high rice blast disease severity was recorded on Kabuye variety (92.59%) in HA. The cultivars Watt (34.1%) and Vuninzara (34.5%) had low rice blast disease severity in MA (Fig. 2).

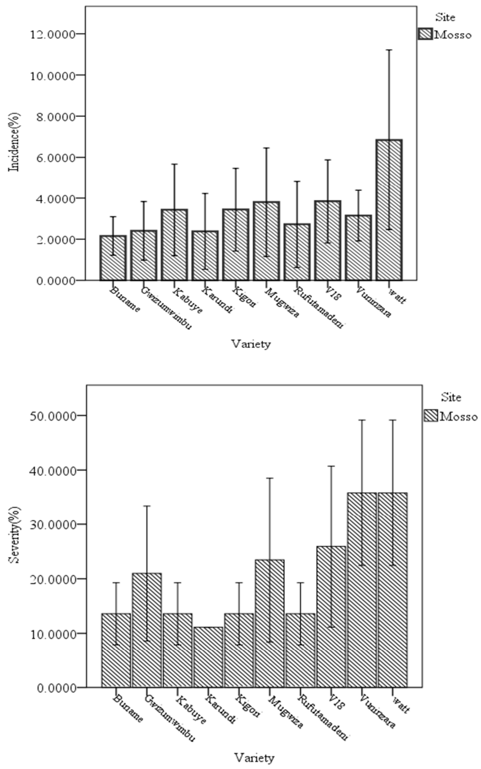

Fig.2. Incidence and severity of rice blast disease of ten cultivars for Middle agro-ecological zone.

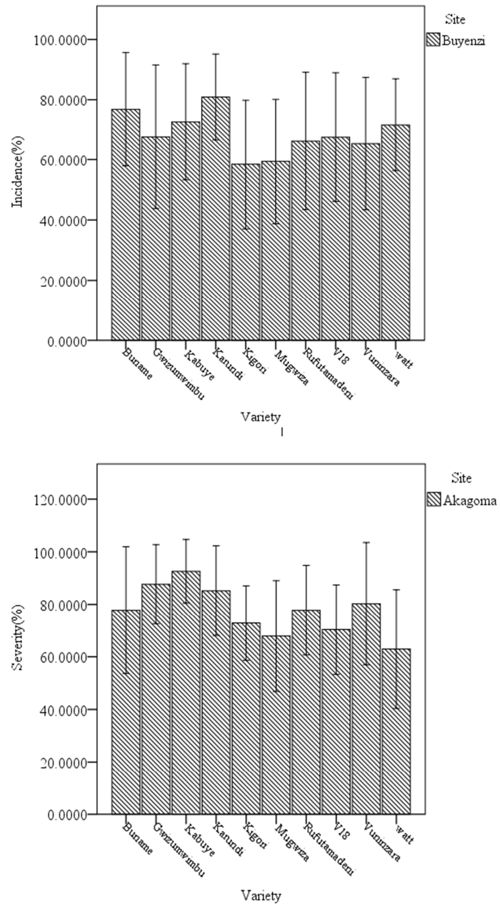

Fig. 3. Incidence and severity of rice blast disease of ten cultivars for High agroecological zone.

Rice blast disease incidence and severity in rice cultivars grown in Middle altitude and High altitude ecologies

The incidence and severity of rice blast disease on ten cultivars at tillering, booting and dough stages in two agro ecologies of Burundi are present in Table 6.

Incidence of rice blast disease in MA was significant different at tillering stage, booting stage and dough stage between cultivars. In the HA zone, the cultivars showed a significant differences in the incidence of the disease at the booting stage. In MA (Mosso region) the highest incidence of the disease was observed on Watt cultivar at tillering (9.67%) and booting (9.83%) stages. While the lowest incidence ranging from 2.49 to 2.77% was recorded on Karundi, Buname, and Gwizumwimbu cultivars at tillering stage. At booting stage, the incidence ranged from 3.07 to 3.88% on the same cultivars. At dough stage, rice blast incidence ranged from 0.49 to 1.68%. In HA (Buyenzi region), the high incidence of rice blast was observed on the cultivars Gwizumwimbu and Buname from 90.05 to 90.82%, and the lowest incidence of disease was recorded on Watt variety (74.12%) at booting stage.

Table 6. Incidence and severity of rice cultivars at different growth stage in Middle altitude A and High altitude ecologies.

Varieties	Mosso region						Buyenzi region					
	Tillering stage		Booting stage		Dough stage		Tillering stage		Booting stage		Dough stage	
	Incidence	Severity	Incidence	Severity	Incidence	Severity	Incidence	Severity	Incidence	Severity	Incidence	severity
Vuninzara	3.48a	33.33ab	4.27a	48.15b	1.68b	25.93a	75.48a	77.78a	87.65ab	85.19a	33.09a	77.78ab
Gwizumwimbu	2.49a	18.52ab	3.35a	25.93ab	1.36ab	18.52a	75.23a	77.78a	90.82b	85.19a	37.00a	100.00b
Mugwiza	4.88a	25.93ab	6.86ab	33.33ab	0.66ab	11.11a	72.22a	77.78a	78.12ab	77.78a	27.95a	48.15a
Kigori	4.58a	11.11a	5.08ab	18.52ab	0.66ab	11.11a	70.57a	70.37a	76.46ab	77.78a	28.33a	70.37ab
watt	9.67b	30.74b	9.83b	48.15b	1.01ab	18.52a	71.11a	62.96a	74.12a	62.96a	69.65a	62.96ab
Kabuye	4.48a	11.11a	5.14ab	18.52ab	0.66ab	11.11a	81.02a	85.19a	88.81ab	92.59a	48.01a	100.00b
V18	4.65a	33.33ab	6.22ab	33.33ab	0.66ab	11.11a	77.69a	70.37a	82.63ab	85.19a	42.2a	55.56a
Karundi	2.77a	11.11a	3.88a	11.11a	0.49a	11.11a	79.92a	85.19a	86.33ab	92.95a	76.44a	77.78ab
Buname	2.54a	11.11a	3.07a	11.11a	0.85ab	18.52a	79.48a	85.19a	90.05b	100.00a	60.92a	48.15a
Rufutamadeni	3.09a	11.11a	4.18a	11.11a	0.90ab	18.52a	75.23a	77.78a	82.35ab	85.19a	41.42a	100.0 b
Mean	4.17	20.74	5.09	25.93	0.9	15.56	75.8	77.04	83.73	84.44	46.5	71.11
CV	60.6	71.1	54.7	60.8	65.00	55.7	10.4	35.3	9.5	23.9	63.3	28.7

Mean in the same column followed by the same letter are not significantly different at $p<0.05$

Severity of rice blast disease was statistically difference at tillering stage and booting stage between cultivars in MA. At tillering stage, the high disease severity was observed on Vuninzara and V18 cultivars (33.33%) at the tillering stage, while the low severity (11.11%) was observed on Kigori, Kabuye, Karundi, Buname and Rufutamadeni cultivars. At booting stage, the highest blast severity was recorded on Watt and Vuninzara cultivars (48.15%), while on Karundi, Buname and Rufutamadeni cultivars (11.11%), rice blast disease severity was recorded lowest.

In HA, rice blast disease severity was significant different at dough stage only between cultivars.

The high blast severity was observed on Gwizumwimbu, Kabuye, and Rufutamadeni cultivars (100%) and the lowest on Mugwiza and Buname cultivars (48.15%) at the dough stage.

Disease severity Index (DSI) on different rice cultivars in two agro ecologies

The results of Table 7 showed that the Disease Severity Index (DSI) on the leaves and panicles was not significantly different (p >0.05) between cultivars at different growth stages in HA region. Significant difference between the cultivars was recorded on severity index at the tillering (p=0.001), booting (p=0.009) and dough stage (p=0.001) in MA (Mosso region).

At tillering stage, Watt variety was recorded with high severity index (6.02%), V18 (1.96%) and Mugwiza (1.74%), while the low severity index was observed on Rufutamadeni variety (0.52%).

Table 7. The rice blast Disease Severity Index at different growth stage.

Varieties	Disease Severity index (%)					
	At tillering stage		At Booting stage		At dough stage	
	Mosso	Buyenzi	Mosso	Buyenzi	Mosso	Buyenzi
Mugwiza	1.74a	28.87a	2.46a	29.43a	0.08a	18.51a
Buname	0.93a	28.8a	0.533a	31.74a	0.38a	22.55a
Watt	6.42b	31.71a	8.00b	32.12a	0.06ab	24.37a
V18	1.79a	27.51a	3.16a	32.71a	0.08a	25.2a
Kigori	0.67a	18.51a	1.99a	25.4a	0.08a	28.77a
Rufutamadeni	0.52a	24.5a	1.08a	25.48a	0.4a	29.54a
Karundi	0.47a	28.37a	0.86a	28.45a	0.05a	29.87a
Gwizumwimbu	0.81a	24.23a	2.81a	25.88a	0.95b	31.7a
Vuninzara	1.36a	24.5a	3.95a	26.45a	0.92c	32.22a
Kabuye	0.69a	31.55a	1.22a	31.58a	0.08a	32.35a
Mean	1.53	26.8	2.61	28.92	0.63	27.5
CV	90	41	77.7	36.8	*	47.2
P. value	0.001	0.921	0.009	0.985	0.001	0.928

Mean in the same column followed by the same letter are not significantly different by Duncan's Multiple Range Test at P<0.05, C.V%=Percent of coefficient of Variation

At booting stage, the high severity index was recorded on Watt variety (8.00%), which was only one different with other cultivars followed by Vuninzara (3.95%), V18 (3.16%), Gwizumwimbu (2.81%) and Mugwiza (2.46%), the low severity index was observed on Buname variety (0.53%). At dough stage, a high severity index was observed on Gwizumwumbu variety (0.95%). The low severity index was recorded on Karundi variety (0.05%), followed by Watt variety (0.06%) and respectively to cultivars Mugwiza, V18, Kigori and Kabuye with severity index of 0.08%. Meteorological factors, including temperature and relative humidity (RH), play an important role in the development of blast severity. In Buyenzi region, the average temperature (16.80C), precipitation (188.7mm) and relative humidity (80.7%) during assessment of disease severity at booting stage (April and May2021) were high. Similar in Mosso region, the average temperature (22.20C), precipitation (120.5mm) and relative humidity (76.7%) were high.

Area under Disease Progress Curve (AUDPC) for two agro-ecologies of Burundi

The area under disease progress curve (AUDPC) is a useful quantitative summary of disease intensity over time, measure of cultivar resistance in disease management. The disease progress was different between rice cultivars, although in all cultivars the disease started slowly and gradually increased exponentially while decrease timed in others (Fig.). Leaf and panicle blast disease progress curves for ten cultivars under field condition are shown in Fig. 3.

The highest AUDPC values were obtained from Rwizumwimbu and Kabuye (6000.00), Karundi and Vuninzar (4666.67), Kigori and Rufutamadeni (4222.22), Watt (3777.78), V18 (3333.33) and Buname and Mugwiza (2888.89) in the region of Buyenzi. However, the trends of blast disease AUDPC were similar for certain Cultivars such as: (1) Gwizumwimbu and Kabuye; (2) Mugwiza, V18 and Buname; (3) Watt; (4) Kigori and Vuninzara.

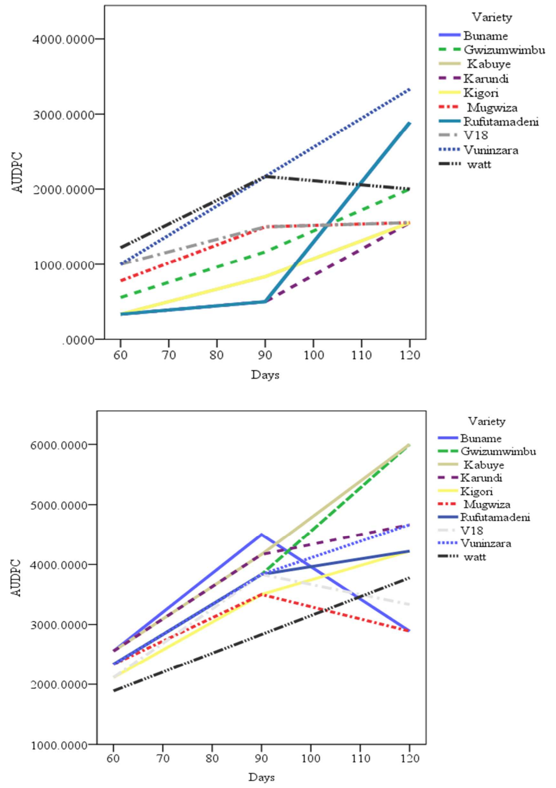

Fig. 4. AUDPC at Mosso (MA) and Buyenzi (HA) region in two agro ecologies of Burundi.

In MA region, there were high AUDPC values recorded in Vuninzara (3333.3), Buname and Rufutamadeni (2888.89), Gwizumwimbu and Watt (2000.00); Kabuye Karundi, Kigori, Mugwiza and V18 (1555.56). Cultivras composed by (1) Mugwiza, Watt and V18; (2) Vuninzara, Kigori and Gwizumwimbu; (3) Rufutamadeni and Kigori, Cultivars showed similar trends of disease progress.

In HA region, the highest AUDPC values on the rice cultivars Gwizumwimbu and Kabuye show a high level of susceptibility to rice blast because the curve has progressed upwards. Kigori and Vuninzara cultivars showed moderate susceptibility to rice blast disease during growth. High resistance to rice blast disease was observed on Bunane variety, followed by V18 and Mugwiza because trends of progress of disease decreased downwards.

In the MA region, Rufutamadeni variety have been highly susceptible to rice blast disease followed by the Karundi variety beacuse the disease progression curves continued to rise upwards. Vuninzara, Gwizumwimbu, and Kigori Cultivars showed moderate susceptibility to the disease. V18, Watt and Mugwiza Cultivars showed a high resistance to the disease, the progression curves decreased downwards.

Watt and Mugwiza Cultivars exhibited the same blast resistance behavior traits in both regions, the disease progression curve decreasing downwards. Similarly, Gwizumwimbu variety showed the trend increased of progress disease in both regions. Watt variety showed appropriate disease progression trend for each region, same as Kigori and Vununzara Cultivars. Following these results obtained, the V18 and Mugwiza cultivars can be grown at the same time in these two regions; Buname variety can be planted in the Buyenzi region and Watt variety in the Mosso region.

Discussion

The study has established the rice crop growing in MA agro ecological zone (AEZ) is less vulnerable to rice blast disease then rice grown in HAAEZ, but in different disease intensities. These findings confirms by Nizigiyimana (1986), who reported that the rice blast disease caused by *Pyricularia oryzae* is known to be a common rice disease in all agro-ecological zones in Burundi. Similarly results were found by Bhat *et al.* (2013), Chuwa (2016), and Shahriar *et al.* (2020), who reported that incidence and severity of rice blast disease vary based on the locations and environments conditions. The results in this study can be ascribed to differences in ecological condition of the two study locations. For instance, higher incidence and severity of the disease were observed in Buyenzi located in HA AEZ which had minimum temperature of 23.6°C and relative humidity of 75.1%. These conditions are similar to those reported by Ahmad *et al.* (2011), that the high rice blast disease incidence and severity is favored by minimum temperature of 20-24°C in night and a high humidity above 90%. Unlike Buyenzi, low rice blast incidence and severity were observed in Mosso region located in MA which had a minimum temperature of 28.4°C and relative humidity of 73.2%. Explanation to this can be the same as in Greer and Webster (2001) who reported that temperature above 28°C favor resistance to blast disease in plants rice.

The low incidence observed in middle altitude zone (Mosso) on different cultivars can be justified by the adaptation to the climate close to their zone of introduction in Imbo plain. However, the high rice blast disease found in HA (Buyenzi region) can be justified by climatic conditions found; another reason may be that some varieties are introduced by farmers' rice (the illegal distribution of seeds between producers). The difference in disease incidence and severity are also supported by Asfaha *et al.* (2015) who observed that the disease incidence or severity vary from low to high on the rice fields depending on the agro-ecological and cultivars differences. Within and between locations differences in cultivar vulnerability to the rice blast at different growth stages were observed in the current study suggesting that age of the plant and the environmental condition. Within and between location differences in cultivar vulnerability to the rice blast at different growth stages were observed in the current study suggesting that age of the plant and environment condition at particular stage could be dictating amount of active inoculum, pathogen virulence and plant resistance. These explanations are in line with Groth and Bond (2007) reported in their finding that incidence and severity of disease depends on inoculums amount, crop growth stage, environment conditions, varietal resistance and cultural management. Puri *et al.* (2006) in his survey on the effect of blast disease over 45 regions of India found high incidence of 30.45% at dough stage in lower land of rice growing areas compared to high altitude zone.

The Area Under Disease Progression Curve (AUDPC) is a parameter that can provide a more prescriptive and practical classification of the disease progression in each variety. This study established 1. Difference cultivars grown in the same AEZ had different rice blast disease progress and 2. Same cultivar grown in different locations had different disease progression. Generally, the progression of the disease tends upwards from the tillering stage to the booting stage, but at dough stage the progression of the disease (AUDPC values) for some cultivars tends upwards and others down. Similar results were supported by Zewdu *et al.* (2017) that the genotypes were significantly different for final leaf blast severity, panicle blast severity, and AUDPC values under field and greenhouse conditions. The results of this study showed that the high value of AUDPC of the blast disease has been recorded in the high altitude region (Buyenzi region). This can be attributed to environmental conditions of regions such as temperature and relative humidity and precipitation.

Another reason for the increased severity of rice blast could be other sources of *P. oryzae* inoculum which may come from other hosts. According to a study carried out by Cui (1995), in certain mountainous regions of the tropical and subtropical zone, the temperature decreases with altitude and, in most of these regions, precipitation increases with altitude; the duration of sunshine and solar radiation is much shorter than in plain areas, and relative humidity and dew are highest at night.

It has been reported that the low night temperature, which is a characteristic of high altitude areas, led to partial strength degradation (Manibhushanrao and Day, 1972), shorter solar radiation, frequent thick fog, and prolonged dew are conducive to rice blast (Changjia *et al.*, 2016). The results of another study done in Fuling and Chongqing on the distribution of rice blast showed that the severity of rice blast was strongly dependent on altitude (Changjia, 1995).

Based on the results found, the Buyenzi region (High altitude) can be considered as a hotspot for rice blast disease while Middle altitude can be considered as a zone of low blast disease because of the observed low incidence and severity of rice blast disease. However, low disease such status in MA might change with pathogen adaptability fitness. Previous studies have demonstrated that pathogen could acquire additional fitness through sexual and parasexual recombination mechanisms under field conditions (Hayashi *et al.*, 1997). Since in this study, the explained hot spot status in HA is based on damage symptoms, it might also change following climatic changes because level of damage is strongly influenced by environmental factors (Liu *et al.*, 2021).

Conclusion

The rice blast disease incidence and severity was significantly different among regions. No significant difference was observed for the main effect interaction location and cultivar. However significant difference of rice blast disease incidence and severity was registered on between cultivars at different growth stages (Tillering, Booting, and Dough stage) in two agro-ecologies of Burundi. V18, Watt and Mugwiza cultivars showed tolerance to the blast disease and can be used in the programs of managing of rice blast disease in both agro ecologies zones. High altitude Agro-ecological zone (HA AEZ) showed a high incidence and severity of disease than the Middle Altitude Agro-ecological zone (MA AEZ). The variations of incidence and severity of rice blast disease in two agro-ecologies zones associated with environmental conditions factors, but also to the illegal introduction of rice varieties by farmers' rice. It is, therefore, important that any program to develop cultivars for resistant to rice blast disease should consider environmental conditions of different locations and cultural practice. More studies are needed for locations not covered by the current study.

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Declaration of competing for interest

The manuscript has no competing interests.

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