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Yield and Agronomic Performance of Selected Bean Varieties against Major Bean Diseases in Rwanda

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Abstract

Bean is one of the most important legume crops in the world. Root rots are widely distributed around the world and are economically important diseases in common beans. Other fungal diseases such as angular leaf spot, anthracnose, ascoshyta leaf spot, rust; viral diseases such as BCMV and BCMNV may also attack and reduce bean yield. After screening bean genotypes (with different background) for root rot resistance, 25 selected genotypes were used to evaluate their resistance level for major bean diseases such as angular leaf spot, anthracnose, ascochyta, rust, bean common mosaic virus, bean common mosaic necrotic virus and to assess their yield. The experiment was carried out using a Randomized Complete Block Design (RCBD) with three replications. The study results have shown that all genotypes were tolerant to anthracnose, ascochyta leaf spot and rust; 9 genotypes (Gasirida, MAC42 × COLTA, MBC71, Mwirasi, RED RANDISPIONEER, RWR 2245 × G12727AB136, RWV 3006 × G122164 AB136, MEXICO 54 × MEXICO 235) were the most tolerant to angular leaf spot; 23 genotypes were tolerant to BCMNV and 9 genotypes (MAC44, RWR 1668, RWR 2154, CIM RM00321, MAC 49, MBC 71, RWR 3194, SC B790, RWR 3228) tolerant to BCMV. Except the number of pods per plant, the effect of genotype on yield components (plants harvested, seed per pod, 100 seed weight and yield) was highly significant among genotypes. 14 genotypes presented a good yield (more than 2t/ha). Climbing genotype MAC 44 was the high yielding genotype followed by Gasirida with a yield of 5.3 tones and 5.0 tones respectively while genotypes namely RWR3228, CAL96, CIMRM00321 and RWR 3194 were the bush bean genotypes with a high yield of 4.8 tones, 3.6 tones, 3.3 tones and 3 tons respectively.

Keywords: Common bean; Phenological parameters; Yield components; Varieties

Introduction

Worldwide, the common bean, *Phaseolus vulgaris L.*, is one of the most important grown food legumes and it is distributed all over 5 continents. In Africa and Latin America bean has been said to be an important source of proteins for both low income urban and rural societies. In Eastern and Southern Africa, bean is very crucial as it serves as a food crop for millions of small holder farmers. In Rwanda, bean is a major crop which is produced on small subsistence farms. Except some exceptions, beans are produced in association with other staple crops such as maize, sorghum, etc. In Rwanda, the bean annual per capita consumption is 37 kg. It provides up to 25% of the total calories and 45% of the total dietary protein. Therefore, this contribution of common bean to people's nutrition is ranked the highest in the world [1].

Beans are eaten as cooked dry or fresh grain, green leaves, or pods. A near-perfect food, they provide a cheap source of quality globulin proteins and micronutrients-iron, zinc, and vitamins-that enhance normal growth and development. To accommodate the environmental diversity of Rwanda, two bean technologies are available to farmers such as bush and climbing beans. Climbing beans grow vertically, requiring staking material, and are harvested over a more continuous period compared to bush beans. This vertical growth property confers climbing beans a yield advantage over bush beans and makes them less likely to be intercropped [2].

However, bean crop has got various constraints that hinder its production. Amongst bean production constraints we have poor agronomic practices, soil infertility, lack of improved cultivars, moisture stress, weed competition and pests and diseases. These constraints if not dealt with, may lead to poor bean performance and subsequent low yield.

Development of cultivars with improved resistance to biotic and abiotic stresses is a primary goal of bean breeding programs throughout the world. Cultivars with improved stress resistance can reduce reliance on pesticides in high input systems, avert risk of yield loss from pests in low-input and high-input systems, and enable more stable bean production across diverse and adverse environments and poor soil conditions. The current study intended therefore to evaluate the yield and agronomic performance of bean varieties against major diseases in Rwanda [3].

Materials and Methods

Site of the study

This study was carried out in the marshland located around Rubona research station, in Rwanda Agriculture and Animal Resources Development Board. This site is located at 1650 m of altitude. The soil of this station is reported to be acidic, low in organic matter, low in exchangeable bases, and low in cation exchange capacity [4].

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Twenty-five genotypes were selected for resistance to root rots after screening 114 bean genotypes including released varieties, local landraces, elite lines, and 300 genotypes introduced from CIAT and MSU. These beans genotypes included climbing and bush type plants that do not require staking materials. Those 25 genotypes were evaluated for disease resistance, yield and other agronomic performances in 2016 C season. Two genotypes MAC 44 and RWR 2154 were used as checks for climbing bean and bush bean respectively (Table 1) [5].

The yield evaluation trial was established in Randomized Complete Block Design with three replicates; each genotype among 25 was planted in small plots made of 4 lines of 2 m each. One seed per station using a spacing of (50 × 10) cm and two seeds per station using spacing of (50 × 20) cm were planted for bush bean and climbing bean respectively [6].

At planting time, fertilizers such as farm yard manure and DAP were applied at the rate of 30 tones/Ha and 100 kg/Ha respectively. Plants were top-dressed with urea 100 kg/Ha at weeding time.

Data collection: During this study, various data related to disease resistance, yield and other agronomic parameters were collected. Data were collected in different crop growth stages. Data about the number of germinated plants were collected one week after planting [7].

During vegetative stage, data on plant vigor and various diseases scored on leaves such as angular leaf spot, anthracnose, ascochyta, rust, bean common mosaic virus, bean common mosaic necrotic virus were recorded using CIAT scale of 1 to 9 where 1 refers to highly resistant and 9 to highly susceptible. The plants were not treated with pesticides in order to determine their resistance or susceptibility to major bean diseases. They were evaluated on the basis of the level of tolerance displayed by their performance in the field [8].

In bean reproductive stage, we collected data about bean growth habit, number of days to flowering, flower color, efficiency, maturing days, plant harvested per plot and pods per plant. During this stage, various diseases evaluated during vegetative stage were also scored considering symptoms appearing on pods using the same scale of 1 to 9. In bean reproductive stage, we collected data about bean growth habit, number of days to flowering, flower color, efficiency, maturing days, plant harvested per plot and pods per plant. Days to flowering were recorded by counting the number of days after emergence when 50% of the plants per plot had the first open flower. Days to maturity was recorded when 90% of pods matured per plot. After harvesting, data related to seed per pods, 100 grain weight, grain weight per plot were recorded [9].

Data analysis: Data were analyzed using GenStat software. Collected data were subjected to analysis of variance. Significant parameters were separated using Fisher's Least Significance Difference test ($P<0.05$) for making mean comparisons.

Results

Diseases scored on bean leaves and pods

Twenty-five varieties were evaluated for fungal foliage diseases such as angular leaf spot, anthracnose, ascochyta, bean rust and viral diseases such as BCMNV and BCMV. The bean fungal disease symptoms were evaluated on both leaves and pods of genotypes under evaluation while BCMNV and BCMV were evaluated only on bean leaves [10].

Analysis of variance results for the reaction of bean varieties against different diseases attacking leaves and pods are found.

According to this study, the analysis of variance for anthracnose, ascochyta leaf spot and rust did not show significant difference among genotypes. All evaluated genotypes were tolerant to the above-mentioned diseases. These genotypes might have got many tolerance/resistance genes against different bean diseases. Cowling, urged that a moderate level of disease resistance is enough especially when it is combined with agronomic or other management packages. Most importantly, these genotypes may serve as sources of resistance in future breeding programs [11,12].

Angular leaf spot, a fungal disease caused by *Phaeoisariopsis griseola* ferraris pathogen, is among the most important and widespread biotic constraint affecting bean production in Africa [13].

In this study, analysis of variance for angular leaf spot showed significant difference ($p<0.05$) among genotypes. The mean separation showed that 9 varieties namely Gasirida, MAC42 × COLTA, MBC71, Mwirasi, RED RANDISPIONEER × MEXICO 235, RED RANDISPIONEER, RWR 2245 × G, RWV 3006 × G122164 AB136, MEXICO 54 × MEXICO 235 are the most tolerant to Angular Leaf Spot (ALS) with a score of less than 2. Those varieties performed better for bean fungus diseases than the checks used in this study. Genetic resistance has been said to provide better and more economical control. Therefore, the 9 resistant genotypes observed in this study could be used for crop improvement programs by incorporating their genes into susceptible commercial varieties (Table 2) [14].

Bean viral diseases such as BCMNV and BCMV were also evaluated during this study. Bean common mosaic virus and Bean common mosaic necrotic virus are the most common and destructive pot viruses known to infect common bean worldwide. Both viruses are seed-borne and transmitted by several aphid species in a non-persistent manner. Disease effect was highly significant for both diseases among genotypes. Out of 25 varieties evaluated, twenty three varieties were tolerant to BCMNV while only 2 varieties were susceptible. Nine genotypes such as MAC44, RWR 1668, RWR 2154, CIM RM00321, MAC 49, MBC 71, RWR 3194, SC B790, RWR 3228 were tolerant to BCMV with a score less than 3. Among them 6 genotypes performed better than the local checks with a score mean of 2.667. Sensitivity of some genotypes indicates that they lack resistance genes while resistant genotypes probably carry resistance genes against available disease strains. This variation in susceptibility to pathogens among plant genotypes was due to different kinds and, perhaps, different numbers of genes for resistance that may be present in each genotype.

Our results on BCMV and BCMNV did not match with the findings on "NL-3K isolate is a stable and naturally occurring interspecific recombinant derived from Bean common mosaic necrosis virus and Bean common mosaic virus" which reported a recombination between strains of BCMV and BCMNV in same genotypes and that in most cases a resistant genotype is not attacked by any of the 2 viruses. Although tested genotypes were screened for resistance to root rot diseases, the above results show that tested varieties are not entirely protected against other bean diseases. Therefore, strategies must be set to maintain these diseases at low incidence and severity levels so as to reduce their effect on bean yield (Table 3).

Variety	Growth habit	Source of seed	Variety	Growth habit	Source of seed
MAC 44	climber	CIAT	MAC 42 × COLTA	climber	Rwanda
GASIRIDA	climber	Rwanda	EQUADOR 299 × G 122164 TU	Semi climber	Rwanda
RWR 3228	Bush	Rwanda	RED RANDISPIONNER × RWV 3006	Semi climber	Rwanda
MAC 49	climber	CIAT	G 122164 TU × EQUADOR 299	Semi climber	Rwanda
MWIRASI	climber	Rwanda	G 12727 AB 136 × G 122164 TU	Semi climber	Rwanda
Rwibarura2	climber	Rwanda	EQUADOR × ACC 714	Semi climber	Rwanda
CAL 96	Bush	CIAT	RWR 1668	Bush	Rwanda
MBC 71	climber	CIAT	G 12727 AB 136 × EQUADOR 299	Semi climber	Rwanda
CIM RM00321	Bush	CIAT	RED RANDISPIONEER × MEXICO 235	Semi climber	Rwanda
RWV 3006 × G122164 AB136	Semi climber	Rwanda	RWR 2245 × G12727AB136	Semi climber	Rwanda
RWR 3194	Bush	Rwanda	MEXICO 54 × MEXICO 235	Semi climber	Rwanda
RWR 2154	Bush	Rwanda	ACC 714	Semi climber	Rwanda
SC B790	Bush	CIAT			

Table 1: List of genotypes used in this study.

Source of variation	DF	ALS	Anthracnose	Ascochyita	Rust
Rep	2	0.4	0.34	0.78	0.04
Genotype	23	0.56*	0.09NS	0.44NS	0.07NS
Error	44	0.27	0.09	0.39	0.07
Mean	-	2.45	1.06	1.24	1.04
CV (%)	-	20.89	27.94	50.25	26.05

Table 2: Fungal diseases scored on bean leaves and pods. Note: NS: Non significant, *significant at the 0.05 probability level.

Source of variation	DF	BCMV	BCMNV
Rep	2	1.52	0.73
Genotype	23	18.41	6.2
Error	44	1.01	1.07
Mean	-	5.65	1.45
CV (%)	-	18.08	71.11

Table 3: Viral diseases scored on bean leaves.

Evaluation of bean yield components: In the course of this study, bean genotype yield components were evaluated. After computing the analysis of variance, it has been revealed that the number of germinated plants, the number of days to flowering, the plant vigor, the efficiency as well as days to maturing were significantly different. The genotypes CAL 96 and Mwirasi germinated better than local check MAC 44 while genotype ACC 714 did not germinate at all. This indicates that germination capacity differs among genotypes. While some varieties can germinate well, others cannot germinate at all. Only 1 genotype performed well compared to bush bean check. Likewise, 1 climbing genotype scored more germinated plants than bean climbing check. The fact that 2 genotypes had high germination rates could probably lead to a positive effect on bean yield. The number of days to flowering varied from 17.33 days to 51 days. The highest number of days to flowering was recorded for genotypes G 12727 AB136 × EQUADOR 299 while the lowest was recorded on MEXICO 54 × MEXICO 235. Compared to the bush bean check, out of 14 bush bean genotypes 9 scored few days to flowering. This could be due to different genetic make-up of considered genotypes and it sounds good because early maturing bean genotypes are needed especially in these days where climate change is impacting negatively on crop yields. In contrary, for climbing bean genotypes, all genotypes scored more days than bean check. This is not good as late maturing varieties are not favored by the current climatic conditions and therefore not preferred by farmers.

The highest plant vigor was recorded on genotypes EQUADOR 299 and G 12727 AB 136X EQUADOR 299 while genotype RWR 2154 showed the lowest vigor. Almost all tested genotypes are more vigorous compared to both local checks. This result which is probably due to genotype make ups was appreciated as plant vigor not only increases the dry matter content but also increases bean yield. The number of days to maturing was higher for genotypes RED RANDISPIONEER × MEXICO 235 and RWV 3006 × G122164 AB136 and lower for genotype SCB 790. Out of 18 bush bean genotypes, 12 scored more days to maturity than local check. All climbing bean genotypes scored more days than check. This indicates that most of tested genotypes are late maturing compared to checks. This is not interesting because late maturing genotypes are not preferred by farmers and thrive less in climate change conditions. Earliness is usually preferred by farmers as it helps avoid late season stresses such as water deficits but may also provide an economic value in terms of providing rapid source of food or marketable product (Tables 4 and 5).

The mean square for yield components such as plants harvested, seeds per pod, 100 seed weight and yield were highly significant while the number of pods per plant was not significant among genotypes. The significant difference observed on grain yield means that genotype has effect on grain yield of bean crop. This finding agrees with the previous finding reported by in his study conducted in Ethiopia on "Evaluation of Common Bean varieties, for yield and yield components". The highest number of harvested bean plants per plot was observed on genotype CAL 96 while the lowest was on genotype RWR 2245 *G12727AB136. Comparing genotypes to their respective checks, seven bush bean genotypes had more harvested plants while only two climbing bean genotypes had more plants, designating that bush beans performed better than climbing beans in regards with this yield parameter. For the seed per pod component, the biggest number was recorded on 2 genotypes namely EQUADOR 299 and G 12727 AB 137XEQUADOR 299 while the lowest was on genotype RED RANDISPIONNER. Among 7 climbing genotypes, only 2 performed better than the check. Among 18 bush bean genotypes, 12 genotypes scored more seeds per pods. This indicates that tested bush bean genotypes are promising because the great number of seed per pod may lead to a subsequent increase of the yield.

The 100 grain weight was higher for genotype MBC 71 and lower for genotype RWR 3228. While all climbing bean genotypes had more grain weight than the check, 5 bush bean performed well than their check. This suggests that those genotypes which scored more grain weight compared to their respective checks could have a good yield [15].

Bean yield was also recorded in this study. Whereas the highest yield was recorded on MAC 44 genotype, the lowest was noted on MEXICO 54 × MEXICO 235. In climbing bean, MAC 44 performed better than all tested genotypes while in bush bean 5 genotypes performed well than the check. Generally, out of 25 genotypes, 14 scored a good yield. Largely, there is a positive correlation between genotypes with good yield components and yield (Tables 6-8).

Source of variation	d.f	No plant germ.	Days to flowering	Flower color	Vigor	Efficiency	Maturing days
Rep	2	58.08	107.89	-	0.55	1.6	47.09
Genotype	23	1138.3	330.32	-	2.07	1.99	218.77
Error	43	48.12	43.93	-	0.32	0.43	48.21
Mean	-	24.2	41.81	-	4.58	4.81	99.67
CV (%)	-	28.67	15.85	-	12.47	13.74	6.98

Table 4: Evaluation of bean yield components.

Source of variation	DF	Plants harvested	Pods/plant	Seed/pod	100 Seed weight	Yield
Rep	2	115.7	650.8	1.42	6.37	784977
Genotype	23	804.35	409.8NS	2.83	386.1	8918602
Error	43	76.66	337.5	0.93	44.17	1091594
Mean	-	22.1	26.9	5.6	74.03	2358
CV (%)	-	38.55	68.29	17.35	8.88	44.3

Table 5: Sources of variations in plants. Note: NS: Non significant.

Genotype	BCMV					Genotype	BCMNV			Genotype	ALS			
GASIRIDA	9	a				RWR 1668	8	a		G 12727 AB 136 X EQUADOR 299	3	a		
EQUADOR X ACC 7 14	9	a	b			G 12727 AB 136 X EQUADOR 299	4	a		Rwibarura2	3	a		
G 12727 AB 136 X EQUADOR 299	8	a	b	c		Rwibarura2	2		b	EQUADOR 299	3	a	b	
MEXICO 54 X II,IEXICO 235	8	a	b	c		RWR 2154	2		b	RWR 3228	3	a	b	

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EQUADOR 299	8	a	b	c			ACC 714	1		b	CAL 96	3	a	b	c
G 122164 TU	8	a	b	c			MEXICO 54 X I'"IEXICO 235	1		b	CII'"I RM00321	3	a	b	c
G 12727 AB 136 X G 122164 TU	8	a	b	c			CAL 96	1		b	EQUADOR X ACC 7 14	3	a	b	c
RED RA)JDISPIONEER X MEXICO 235	8	a	b	c			CIM RM0032 1	1		b	G 12727 AB 136 X G 122164 IU	3	a	b	c
RWR 2245 X G12727AB 136	8	a	b	c			EQUADOR 299	1		b	MAC 44	3	a	b	c
RED RA)JDISPIONNER 0	7		b	c			EQU DOR X ACC 714	1		b	MAC 49	3	a	b	c
MWIRASI	7		b	c			G 122164 IU	1		b	RWR 3194	3	a	b	c
Rwibarura2	7			c	d		G 12727 AB 136 X G 122164 IU	1		b	SC B790	3	a	b	c
RWV3006 X G122164 AB 13-6	7			c	d		GASIRIDA	1		b	RWR 1668	2		b	c
MAC 42 X COLTA	6				d		MAC 42 X COLTA	1		b	ACC 7 14	2		b	c
ACC 714	6				d		MAC 44	1		b	G 122164 IU	2		b	c
CAL 96	4					E	MAC 49	1		b	RWR 2154	2		b	c
MAC 44	3					E	MBC 7 1	1		b	GASIRIDA	2			c
RWR 1668	3					E	MVIIRASI	1		b	-MAC 42 X COLTA	2			c
R\VR 2154	3					E	RED RANDISPIONEER X II·IEXICO 235	1		b	MBC 71	2			c
CIM RM00321	3					E	RED RANDISPIONNER 0	1		b	M\VIRASI	2			c
llt"C 49	3					E	RWR 2245 X G12727AB 136	1		b	RED RANDISPIONEER X MEXICO 235	2			c
I\IBC 71	3					E	RWR 3!94	1		b	RED RANDISPIONNER 0	2			c
RWR 3194	3					e	RWR 3228	1		b	RWR 2245 X G12727AB 136	2			c
SC B 790	3					E	RWV 3006 X G122164 AB 136	1		b	RWV 3006 X GI 22164 AB 136	2			c
RVIR 3228	2					E	SC B 790	1		b	.MEXICO 54 X MEXICO 235	2			c

Table 6: Mean score and rank of BCMV, BCMNV and ALS diseases.

Genotype	Plant vigor								Genotype	Days to flowering			Genotype	Maturing days				
EQUADOR 299	6	a							G 12727 AB 136 X EQUADOR 299	51	a		RED RANDISPIONEER X MEXICO 235	109	a			
G 12727 AB 136 X EQUADOR	6	a							G 12727 AB 136 X G 122164 TU	5 1	a		RWV 3006 X G 122 I 64 AB 136	109	a			
G 12727 AB 136 X G 122164	6	a							G 122 164 TU	48	a		EQUADOR X ACC 7 14	107	a			
EQUADOR X ACC 7 14	5	a	b						Rwibarura2	48	a		RWR 2245 X G 12727AB 136	107	a			
RED RANDISPIONEER X ME	5	a	b						EQUADOR 299	48	a		MEXICO 54 X MEXICO 235	107	a			
RED RANDISPIONNER O	5	a	b						EQUADOR X ACC 7 14	48	a		GASIRIDA	107	a			
RWR 2245 X G 12727AB 136	5	a	b						R\W 3006 X G 122164 AB 136	48	a		MWIRASI	106	a			
G 122 164 TU	5	a	b	c					GASIRIDA	48	a		G 12727 AB 136 X EQUADOR 299	105	a			

GASIRIDA	5	a	b	c					MWIRASI	47	a		RED RANDISPIONNER O	105	a			
MAC 42 X COLTA	5	a	b	c					RED RANDISPIONEER X MEXICO 235	47	a		G 12727 AB 136 X G 122164 IU	104	a			
MWJRASI	5	a	b	c					MAC 42 X COLTA	47	a		EQUADOR 299	104	a			
Rwibarura2	5	a	b	c					MAC 49	47	a		G 122 164 TU	104	a			
MEXIC0 54 X MEXIC0 235	5	a	b	c	d				MBC 7 1	47	a		Rwibarura2	103	a			
R\W 3006 X G 122164 AB 136	5	a	b	c	d				MAC 44	47	a		MAC 42 X COLTA	102	a			
ACC 7 14	5	a	b	c	d	e			RWR 2245 X G 12727 AB 136	45	a	b	b MAC 49	101	a	b		
SC B 790	4			c	d	e			RWR 2 154	42	a	b	b MAC 44	100	a	b		
MAC 49	4				d	e	F		CIM RM00321	40	a	b	b MBC 71	100	a	b		
MBC 7 1	4				d	e	F		SC B790	40	a	b	b ACC 7 14	100	a	b	c	
RWR 1668	4				d	e	F		RWR 3194	39	a	b	b RWR 1668	91		b	c	d
CAL 96	4					e	F	g	RWR 3228	39	a	b	b RWR 2154	90		b	c	d
CIM RM00321	4					e	F	g	RWR 1668	39	a	b	b CIM RM00321	88			c	d
RWR 3 194	4					e	F	g	CAL 96	38	a	b	b RWR 3228	88				d
MAC 44	3						F	g	Red RANDISPIONNER 0	32		b	b RWR 3194	86				d
RWR 3228	3						F	g	MEXIC0 54 X MEXIC0 235	32		b	b CAL 96	85				d
RWR 2 154	3							g	ACC 7 14	32		b	SC B 790	82				d

Table 7: Mean days to flowering, days to maturing and plant vigor of tested genotypes.

Genotype	Number of plant germinated plants								Genotype	Number of harvested plants								Genotype	Yield (Kg/ha)							
CAL 96	57	a							CAL 96	51	a							MAC 44	5321	a						
MWIRASI	52	a	b						Rwibarura2 MWIRASI RWR 3228	44	a	b						GASIRIDA	5025	a	b					
MAC 44	47	a	b	c					MAC 44	42	a	b	c					RWR 3228	4800	a	b	c				
RWR 2154	47	a	b	c	d				GASIRIDA	37	a	b	c	d				MAC 49	4258	a	b	c	d			
Rwibarura2	46	a	b	c	d				MWIRASI	37	a	b	c	d				MWIRASI	4083	a	b	c	d			
RWR 3228	41		b	c	d	e			RWR 3228	37	a	b	c	d				Rwibarura2	3663	a	b	c	d	e		
RWR 1668	39			c	d	e			RWR 3 194	35		b	c	d	e			CAL 96	3638	a	b	c	d	e		
RWR 3194	38			c	d	e			CIM RM00321	35		b	c	d	e			MBC 7 1	3575		b	c	d	e		
GASIRIDA	37			c	d	e	f		RWR 2 154	34		b	c	d	e			CIM RM00321	3329		b	c	d	e		
MAC 49	37			c	d	e	f		MAC 49	32		b	c	d	e			RWV 3006 X G 122164 AB 136	3267			c	d	e		
CIM RM00321	36				d	e	f		RWV 3006 AB 136 X G122164 AB136	30		b	c	d	e			RWR 3 194	3075				d	e	f	
RWV 3006 X 0122 164;UI I 36	33					e	f	g	MBC 7 1	26			c	d	e			RWR 2 154	2996				d	e	f	
MBC 71	26						f	g	SC B790	26			c	d	e			SC B790	2925				d	e	f	
SC B 790	26						f	g	MAC 42 X COLIA	21					e	f	g	MAC 42 X COLTA	2088					e	f	g

MAC 42 X COLTA	21								h	i		RWR 1668	9						f	g	h	EQUADOR 299	1429						f	g	h
RED RANDISPIONEER X MEXICO 235	8									i	j	RED RANDISPIONEER X MEXICO 235	7							g	h	RED RAN. DISPIONEER X MEXICO 235	1383						f	g	h
EQUADOR 299	5									i	j	EQUADOR 299	5								h	G 122164 TU	867							g	h
G 12727 AB 136 X EQU.@OR 299	5									i	j	G 12727 AB 136 X EQUADOR 299	5								h	G 12727 AB 136 X G 122164 TU	733							g	h
G 12727 AB 136 X G 122 164 TU	4									i	j	G 12727 AB 136 X G 122164 TU	4								h	EQUADOR X ACC 7 14	650							g	h
EQUADOR X ACC 7 14	4									i	j	EQUADOR X ACC 7 14	3								h	RWR 1668	517							g	h
G 122 164 IU	2									i	j	MEXICO 54 X MEXICO 235	2								h	G 12727 AB 136 X EQUADOR 299	483							g	h
RWR 2245 X G 12727AB 136	2									i	j	G 122 164 TU	2								h	RED RAN. DISPIONNER 0	463							g	h
MEXICO 54 X MEXICO 235	2										j	RED RANDISPIONNER 0	1								h	RWR 2245 X G l2727 AB 136	208								h
RED RANDISPIONNER 0	1										j	RWR 2245 X G 12727 AB 136	1								h	MEXICO 54 X MEXICO 235	183								h
ACC 7 14	0										j	ACC 7 14	0								h	ACC 7 14	0								h

Table 8: Mean yield, number of plants germinated and harvested of tested genotypes.

Discussion

Diseases scored on bean leaves and pods

Twenty-five varieties were evaluated for fungal foliage diseases such as angular leaf spot, anthracnose, ascochyta, bean rust and viral diseases such as BCMNV and BCMV. The bean fungal disease symptoms were evaluated on both leaves and pods of genotypes under evaluation while BCMNV and BCMV were evaluated only on bean leaves. Analysis of variance results for the reaction of bean varieties against different diseases attacking leaves and pods [16].

According to this study, the analysis of variance for anthracnose, ascochyta leaf spot and rust did not show significant difference among genotypes. All evaluated genotypes were tolerant to the above-mentioned diseases. These genotypes might have got many tolerance/resistance genes against different bean diseases. Cowling, urged that a moderate level of disease resistance is enough especially when it is combined with agronomic or other management packages. Most importantly, these genotypes may serve as sources of resistance in future breeding programs. Angular leaf spot, a fungal disease caused by *Phaeoisariopsis griseola (Sacc.)* Ferraris pathogen is among the most important and widespread biotic constraint affecting bean production in Africa [17].

Conclusion

In this study on evaluation of bean disease tolerance and yield assessment of twenty-five genotypes resistant to root rot diseases, there were significant variations observed among the common bean varieties for all the yield and yield components except number of pods per plant. Six climbing genotypes yielded better with more than 3.5 tons per hectare and seven bush genotypes yielded more than 2.9 tons per hectare. In addition to high yield expressed by the above mentioned genotypes, all of them were tolerant to bean root rots, anthracnose, ascochyta leaf spot and bean rust and most of them tolerant to BCMNV. The result of analysis of variance showed that the yield parameters studied were significantly affected by genotypes. The high yielding genotypes with moderate to high levels of tolerance to most diseases would not only be recommended to bean farmers but also they would serve as source of resistance in further bean breeding initiatives.

This study was conducted only in Rubona research center, it is recommended to repeat the same study in multiple environments as environmental conditions play a significant role in the development and spread of these diseases. This could contribute to an increase in agricultural production and improve common bean productivity in Rwanda.

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