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EVALUATION OF INTRODUCED BEAN GENOTYPES FOR ADAPTABILITY AND ROOT ROT RESISTANCE IN RWANDA

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ABSTRACT

Common bean (Phaseolus vulgaris) is an important food crop in Rwanda as it contributes to food security and income generation. Resistance to root rot disease in introduced genotypes is insufficient for consideration as superior without evaluation for yield potential. The objective of this study was to evaluate the performance of different introduced genotypes under Rwandan conditions and to assess their resistance to bean root rot diseases. A total number of 570 genotypes including 300 genotypes introduced from CIAT coded ADP, 18 locally developed inbred lines high iron and zinc content and 252 genotypes introduced from Michigan State University (MSU) were evaluated in Rubona and Akanyirandoli experimental sites of Rwanda Agriculture and Animal Resources Development Board. Out of the 300 introduced genotypes, 76 candidates were selected for future intermediate trials. Among the 76 genotypes evaluated during intermediate trials, 5 genotypes including ADP47, ADP48, ADP53, ADP57 and ADP93 were selected based on yield performance for further evaluation in advanced yield trials. All ADP lines performed poorly compared to the rest of tested entries. Only ADP48 was kept for further evaluation due to its superior performance which was twice that of other ADP lines. The best locally bred materials included 2015AN004, 2015AN012, 2015AN15, 2015AN011, 2015AN010, and 2015AN005 with a mean yield ranging between 1083 and 1449 kg ha-1. Among the 252 introduced genotypes from MSU, though none survived the stress under field conditions, 15 were found to be resistant, 115 were tolerant and 122 were susceptible to the endemic root rot diseases in Rwanda.

Keywords: Yield, Bush Bean, root rot, Rwanda

1. INTRODUCTION

Common Bean (*Phaseolus vulgaris*) is an important crop in Rwanda as it contributes to food security and income generation (Larochelle *et al.*, 2016). The annual per capita consumption of common bean is higher among low-income people who cannot afford to buy nutritious food stuff such as fish and meat (Namugwanya *et al.*, 2014). According to Larochelle *et al.*, 2014, Rwanda has been the highest per capita bean consumption (around 29-60 kg per person per year) in the world; hence it's a key crop for food security. Despite this importance, bean yields have drastically declined over the past years (FAO, 2018). This is due to various factors, among them predominance of cultivars susceptible to numerous biotic and abiotic stresses (Rodriguez De

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Luque *et al.*, 2014; Kajumula and Muhamba, 2012). Common varieties of bean grown in Rwanda are bush and climbing types each having a particular benefit. In land constrained fields, the vertical production of climbing beans increases land use efficiency over bush type varieties. However, bush bean management can be simpler, and the earlier maturity is sometimes preferred (Katungi *et al.*, 2016). Unfortunately, bush beans are severely affected by diseases especially root rots (Rusuku *et al.*, 1992), climate change and variability in precipitation. For instance, legume production went down in 2004 due to heavy rains in high altitude regions, which are generally more productive regions (Mikova *et al.*, 2015). Generally, under stress conditions, root rot disease cause significant yield losses to bean production (Abawi and Ludwig, 2005). Nzungize *et al*. (2012) reported yield losses of up to 70% in bush beans due to root rot disease in Rwanda. Empirical evidence shows that poverty would have been 0.4 higher in Rwanda in the absence of the development and adoption of improved bean varieties (Rodriguez De Luque *et al.*, 2014; Larochella *et al.*, 2013)

In order to address these issues, the adoption of new crop technologies like improved varieties and use of good agricultural practices is needed. Moreover, as highlighted by Larochelle *et al.*, (2014) food security would have been decreased in absence of adoption of improved bean varieties in Rwanda. Increased in yield as a results of using improved varieties has been reported in Uganda (Sebuwufu *et al.*, 2015), in Kenya and Ethiopia (Katungi *et al.*, 2010). The introduction of high yielding, disease tolerant varieties with quality characteristics acceptable to the local market is essential to the improvement of local production (Richardson, 2011). Therefore, the resistance to root rot disease in introduced genotypes alone is not sufficient for consideration as superior without evaluation for yield and local adaptation.
Through collaboration between Rwanda Agriculture and Animal Resources Development Board (RAB) and CGIAR centers, several genotypes presumed to be resistant to root rot(s) were introduced to assess their adaptability in Rwandan environment. Therefore, the objective of this study was to evaluate the performance of different introduced genotypes under Rwandan conditions and to assess their resistance to bean root rot diseases.

2. Materials and Methods

A total number of 300 genotypes were introduced from CIAT coded ADP for adaptability test and evaluation of root rot resistance. The Andean Diversity Panel (ADP) was assembled by Cichy *et al*. (2015) to represent the diversity of Andean bean genotypes, varieties and landraces from South and North American and East Africa. They were planted in a screening nursery at Rubona in October 2013 and late July 2014 for preliminary trials. Each genotype was planted in two replicated plots of two by one meter consisting of two rows.

A second set of 252 genotypes of bush bean were introduced from Michigan State University (MSU) for root rot resistance evaluation. The study was conducted at RAB research field site located at Akanyirandoli, Nyamagabe district. Each genotype was planted in unreplicated plots of three by one meter consisting of two rows using an augmented design. Plant spacing, fertilizer application and other agronomic practices were followed similar to the ADP nursery.

Candidate genotypes selected for intermediate trials were conducted in November 2014, late March and July 2015 in Rubona, (1706m; S2° 48'; E29° 76') and Akanyirandoli (2153m; S20° 30' 43.2"; E29° 30' 007"), Rwanda Agriculture and Animal Resources Development Board research fields, Huye and Nyamagabe districts respectively. Both sites were selected because they are hot spots for the root rot bean disease complex. Superior genotypes selected for advanced trials were evaluated in late October 2015 and late March 2016 in Nyamagabe and Rubona research fields. The figure 1 describes the weather conditions during experimental period.

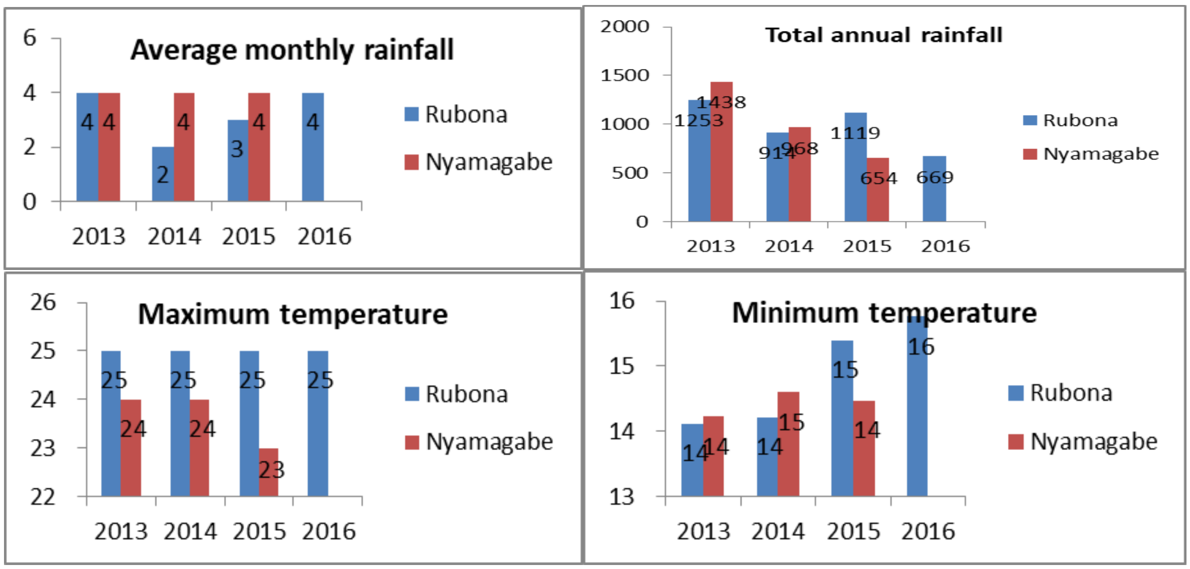

Figure 1: Weather conditions during the experimental period

In addition to these selected genotypes, eighteen high iron and zinc content inbred lines locally developed were evaluated together. Moreover, local and improved (RAB) bean varieties were used as checks for root rot disease (RRD) resistance. Each genotype was planted in three replicated plots of two by two meters consisting of four rows.

For all experiments, the field was ploughed twice prior good seed bed preparation and sowing. At the day of planting, well-composted farm yard manure (30t/ha) and DAP (100kg/ha) were applied. Then, one seed was planted per hole at spacing of 50cm between rows and 10cm within rows. During the process of hilling up the bean rows, 100kg/ha of Urea was applied. Weeding was carried out when necessary however, no pesticides were applied to control weeds.

Data collection

Selection of genotypes was based on growth parameters and diseases occurrence. The parameters included; plant vigor, pod efficiency, days to flowering, days to maturity, plant harvested/plot, pod/plant, grains/pod and yield. Natural disease infections were assessed for; Angular leaf spot, Ascochyta blight, *Bean common mosaic necrosis virus* (BCMNV), *Bean common mosaic virus* (BCMV), Common bacterial blight, Bean rust and root rots using 1-9 scale (CIAT, 2012).

Root rot disease was assessed twenty-one days after emergence. Ten plants were randomly selected per genotype and were uprooted taking care not to damage roots then washed to remove adhering soil. The roots were excised, observed for disease symptoms and scores given, based on a 1 to 9 disease scale, (CIAT, 1987) as: 1= No visible disease symptoms; 9 = Approximately 75% or more of the hypocotyl and root tissues affected with advanced stages of rotting combined with a severe reduction in the root system.

Data Analysis

All experimental results were analysed using Microsoft Excel, Genstat statistical software package, the analysis of variance and coefficient of variation (% CV) were performed and mean values or Least Significant Differences (LSD) were compared using the procedures of Duncan's at the 5% level of significance.

Preliminary trial results

Out of the 300 introduced genotypes evaluated, 76 candidates were selected for future intermediate trials. Significant differences were observed among genotypes on yield performance at P<0.05 (Table 1). Significant differences were observed between genotypes in terms of plant vigor (P<0.001), pod efficiency (P=0.007) and yield (P<.001) (Table 2a, b, c, d). The average yield ranged from 0.1kg ha^{-1} for ADP114 to 1612 kg ha^{-1} for ADP282. Compared to the control RWR 2245 which yielded 1076 kg ha^{-1}, the top yielding 16 APD lines ranged in yield from 1612 to 1081 kg ha^{-1}. No significant difference (P>0.05) was observed for Angular leaf spot, Ascochyta blight and bean rust disease. However, there was significant differences (P< 0.05) for reaction to Bean Common Mosaic Necrotic Virus (BCMNV) and Bean Common Mosaic Virus (BCMV)

Table 1: Analysis of variance of yield performance of 76 selected entries bred and introduced for resistance to bean root rot in 2015.

Source of variation	D.F.	S.S.	M.S.	V.R.	F pr.
Environments	2	727082	363541	3.06	0.049
Entries	75	15283204	203776	1.71	0.002
Residual	202	24005445	118839		
Total	279	40015731	143426		
GM			467.2		
CV%			74		

Root rot evaluation was done at Rubona under field conditions with 76 entries evaluated in 2015B in 3 replications. Entries including ADP666, ADP103, ADP50, ADP44, ADP6, ADP214, ADP52, ADP61, ADP54, ADP39, ADP57, ADP211 performed above average with higher levels of resistance than the rest of evaluated entries. At Akanyirandori, all evaluated lines were susceptible to bean fly where the whole nursery was destroyed.

Table 2a: Growth and disease data of the seventy-six genotypes selected from the preliminary trials

Genotypes	**Plant vigor**	**Pod Efficiency**	**Yield** kg ha^{-1}	**Angular leaf spot**	**Ascochyta blight**	**BCMNV**	**Bean Rust**	**BCMV**
ADP4	5.0	7.0	748	4.5	2.2	1.0	1.8	5.3
ADP6	4.8	6.5	771	4.2	2.5	1.0	2.8	4.3
ADP8	**5.0**	**7.3**	**1090**	**4.5**	**2.0**	**1.0**	**2.0**	**4.8**
ADP10	5.0	6.3	846	3.0	2.2	1.0	3.0	5.3
ADP11	5.5	6.8	911	5.0	3.0	1.0	2.3	6.8
ADP18	5.0	7.0	753	3.0	2.0	1.0	2.8	4.8
ADP19	4.8	7.0	769	3.2	2.0	1.0	3.0	6.3
ADP21	6.0	7.5	530	2.0	1.7	1.0	2.0	6.5
ADP26	4.8	6.0	931	3.5	2.2	1.0	2.0	4.0
ADP29	4.8	6.8	759	3.7	2.2	1.0	3.3	7.3
ADP30	4.5	6.5	736	4.0	3.0	1.0	1.8	4.3
ADP31	4.8	6.5	840	5.0	2.7	1.0	3.3	6.8
ADP32	**4.0**	**5.8**	**1345**	**4.7**	**2.2**	**1.5**	**1.8**	**5.3**
ADP36	4.8	6.3	890	2.5	1.7	1.0	1.8	6.5
ADP37	**4.5**	**6.5**	**1083**	**3.7**	**2.5**	**1.0**	**2.3**	**5.3**
ADP38	5.0	7.0	701	4.0	3.2	1.0	2.0	5.5
ADP43	**4.8**	**7.0**	**1415**	**4.0**	**2.5**	**1.7**	**1.5**	**6.3**
ADP44	**4.8**	**6.3**	**1081**	**3.5**	**2.0**	**1.0**	**1.8**	**6.3**
ADP45	5.5	7.5	750	3.2	2.0	1.0	2.5	6.8
RWR 2245 (Check)	4.4	6.2	1076	3.1	2.2	1.21	1.6	3.1
P value	**<.001**	**0.007**	**<.01**	**0.479**	**0.991**	**<.001**	**0.996**	**<.001**
% CV	**20.42**	**21.73**	**60.83**	**52.59**	**44.21**	**83.97**	**78.08**	**34.88**

1 to 9 disease scale, where1= No visible disease symptoms; 9 = Approximately 75% of the plant part affected

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Table 2b: Growth and disease data of the seventy-six genotypes selected from the preliminary trials

Genotypes	Plant vigor	Pod Efficiency	Yield kg ha^{-1}	Angular leaf spot	Ascochyta blight	BCMNV	Bean Rust	BCMV
ADP46	**4.8**	**5.8**	**1315**	**4.0**	**2.2**	**1.0**	**2.0**	**6.0**
ADP47	**4.5**	**6.5**	**1150**	**3.5**	**2.7**	**1.0**	**2.3**	**7.0**
ADP48	5.0	6.5	963	5.5	3.2	1.0	2.5	7.5
ADP49	4.8	7.3	894	3.7	2.1	3.5	2.8	5.6
ADP50	**4.3**	**6.0**	**1316**	**4.2**	**3.2**	**1.0**	**2.0**	**5.8**
ADP51	4.8	6.5	824	3.0	3.0	1.0	2.5	6.0
ADP52	5.3	6.8	703	3.7	2.7	1.0	2.0	5.5
ADP53	4.5	6.5	908	3.7	2.0	1.0	3.0	6.0
ADP54	5.0	6.5	946	3.0	1.7	1.0	3.3	7.5
ADP56	5.0	6.7	844	4.4	2.4	1.1	3.0	7.7
ADP57	**4.5**	**6.3**	**1316**	**4.2**	**2.5**	**1.0**	**2.0**	**6.5**
ADP58	**4.3**	**6.0**	**1303**	**3.5**	**2.2**	**1.0**	**2.8**	**5.5**
ADP59	5.5	7.5	801	3.5	2.5	1.0	2.5	7.3
ADP60	**4.8**	**7.3**	**1203**	**4.0**	**3.2**	**1.0**	**1.8**	**8.3**
ADP61	**4.8**	**7.0**	**1103**	**3.0**	**2.2**	**1.0**	**1.8**	**4.5**
ADP62	4.8	7.0	766	3.5	2.5	1.0	2.8	6.8
ADP64	4.5	7.0	825	3.2	2.7	1.0	2.5	7.8
ADP66	4.8	6.5	939	4.7	2.5	1.0	2.3	6.8
ADP69	6.0	6.8	612	3.7	1.7	1.0	2.3	6.8
RWR 2245 (Check)	4.4	6.2	1076	3.1	2.2	1.21	1.6	3.1
P value	**<.001**	**0.007**	**<.01**	**0.479**	**0.991**	**<.001**	**0.996**	**<.001**
% CV	**20.42**	**21.73**	**60.83**	**52.59**	**44.21**	**83.97**	**78.08**	**34.88**

1 to 9 disease scale, where1= No visible disease symptoms; 9 = Approximately 75% of the plant part affected

Table 2c: Growth and disease data of the seventy-six genotypes selected from the preliminary trials

Genotypes	Plant vigor	Pod Efficiency	Yield kg ha^{-1}	Angular leaf spot	Ascochyta blight	BCMNV	Bean Rust	BCMV
ADP70	4.6	5.7	936	4.1	2.7	1.1	3.6	7.0
ADP77	4.8	6.8	739	3.2	2.5	1.0	2.0	7.0
ADP81	5.8	7.5	606	2.7	2.2	1.0	2.0	6.3
ADP89	4.5	6.3	931	5.0	2.5	1.0	2.5	4.8
ADP93	5.0	6.5	1065	3.7	2.2	1.0	2.5	6.3
ADP94	**4.5**	**6.0**	**1119**	**3.0**	**3.0**	**1.5**	**2.5**	**3.5**
ADP100	4.3	6.5	936	4.2	3.2	1.0	2.3	3.8
ADP103	4.3	5.8	914	3.0	3.2	1.0	1.5	2.8
ADP125	4.5	7.0	735	5.0	2.5	1.0	5.3	4.0
ADP188	**4.5**	**6.8**	**1106**	**4.0**	**2.2**	**1.0**	**2.3**	**4.8**
ADP211	4.8	7.0	911	3.2	2.2	1.0	1.5	6.0
ADP212	5.5	7.0	689	3.2	2.0	1.0	2.0	5.3
ADP214	4.0	6.5	1031	2.0	1.7	1.0	2.8	6.3
ADP220	4.8	7.0	938	4.0	2.2	2.2	2.0	5.5
ADP232	5.3	7.0	753	3.5	2.2	1.5	3.0	5.0
ADP282	**4.1**	**6.9**	**1612**	**1.8**	**2.9**	**0.8**	**1.1**	**7.0**
ADP367	4.8	7.5	878	4.7	2.2	1.0	3.8	6.8
ADP379	5.7	6.3	902	3.9	2.0	0.9	3.0	6.3
ADP390	5.3	7.0	734	4.5	2.5	1.0	1.8	4.8
RWR 2245 (Check)	4.4	6.2	1076	3.1	2.2	1.21	1.6	3.1
P value	**<.001**	**0.007**	**<.01**	**0.479**	**0.991**	**<.001**	**0.996**	**<.001**
% CV	**20.42**	**21.73**	**60.83**	**52.59**	**44.21**	**83.97**	**78.08**	**34.88**

1 to 9 disease scale, where1= No visible disease symptoms; 9 = Approximately 75% of the plant part affected

Table 2d: Growth and disease data of the seventy-six genotypes selected from the preliminary trials

Genotypes	Plant vigor	Pod Efficiency	Yield kg ha^{-1}	Angular leaf spot	Ascochyta blight	BCMNV	Bean Rust	BCMV
ADP391	5.3	7.3	801	3.5	3.0	1.0	3.5	4.8
ADP439	6.5	7.5	261	6.0	3.5	1.0	2.8	8.0
ADP445	5.5	8.0	300	5.2	2.2	3.7	2.5	5.3
ADP446	4.4	7.0	769	2.9	2.0	4.9	2.4	5.3
ADP455	4.8	7.3	655	2.7	2.7	1.0	1.8	4.8
ADP467	4.8	6.3	940	3.0	2.5	1.0	2.0	4.3
ADP468	5.0	6.3	934	3.0	2.2	1.0	1.8	5.5
ADP469	5.8	7.3	713	4.7	2.7	1.0	1.8	6.0
ADP489	5.0	6.8	780	4.7	2.5	1.0	2.3	5.5
ADP503	4.8	7.5	639	3.5	3.0	1.0	2.0	6.8
ADP521	**5.3**	**7.3**	**1086**	**3.5**	**3.0**	**2.0**	**2.0**	**6.0**
ADP603	4.8	6.4	860	3.5	2.5	2.0	2.5	3.0
ADP612	5.3	6.8	778	4.2	3.2	1.0	2.0	4.8
ADP615	3.8	5.8	649	2.0	1.5	4.7	2.0	2.8
ADP647	5.3	7.3	648	3.7	2.7	1.0	2.5	3.5
ADP665	4.8	6.5	636	3.2	2.2	1.0	3.0	3.3
ADP666	5.0	7.0	679	2.2	2.0	1.0	2.0	3.3
ADP670	5.3	7.3	613	2.0	2.0	1.7	2.0	4.8
ADP683	5.5	6.8	725	4.5	2.5	4.0	2.0	4.8
RWR 2245 (Check)	4.4	6.2	1076	3.1	2.2	1.21	1.6	3.1
P value	**<.001**	**0.007**	**<.01**	**0.479**	**0.991**	**<.001**	**0.996**	**<.001**
%CV	**20.42**	**21.73**	**60.83**	**52.59**	**44.21**	**83.97**	**78.08**	**34.88**

1 to 9 disease scale, where1= No visible disease symptoms; 9 = Approximately 75% of the plant part affected

Intermediate trial results

Among the 76 genotypes evaluated during intermediate trial, 5 genotypes were selected based on yield performance for further evaluation in advanced yield trial. The selected genotypes are ADP47, ADP48, ADP53, ADP57 and ADP93 all having less yield compared to local check (Table 3).

Table 3: Five genotypes selected based on yield performance

Genotypes	Plant vigor	Days to flowering	Days to maturity	Yield kg ha^{-1}
ADP47	4.3	39.3	77.3	680
ADP48	5.0	39.3	77.7	883
ADP54	4.3	41.3	80.0	621
ADP57	5.0	41.6	80.3	780
ADP93	4.5	39.0	71.0	833
LOCAL CHECK	4.5	32.0	69.3	895
RAB CHECK	4.7	30.8	70.7	1280
P value	**<.001**	**<.001**	**0.023**	**<.001**
% CV	**18.88**	**6.24**	**3.38**	**50.38**

Vigor: 1 to 9 disease scale, where1= Good vigor; 9 = Poor vigor

Advanced trial

Anthracnose, Ascochyta blight, common bacterial blight and bean rust diseases were not observed on pods. The majority of ADP lines performed poorly compared to the rest of tested entries (Table 4). Only ADP48 was retained for it superior 2-fold performance compared to other ADP lines. Significant differences were observed among genotypes on yield (P<0.001, pods/plant (P<0.001), harvested plants per plot (P<0.001), days to flowering (P<0.001 and plant vigor), rust on leaves (P<0.001), bean common mosaic virus (P<0.01), anthracnose on leaves (P<0.05) and angular leaf spot on pods (P<0.01). The two genotypes with mean yield of 900 kg ha-1 and 832 kg ha-1 outperformed both the local and improved checks while 9 genotypes performed better than the local check (Table 4). Differences in genotypic performance were probably due to unfavorable conditions during the growth period.

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Table 4: Agronomic data of the five introduced genotypes and local inbred lines evaluated in advanced trials

Genotypes	Plant vigor	Days to flowering	Days to maturity	Plant harvested/plot	Pod/ plant	Grains/pod	Yield kg ha^{-1}
2015ANB 001	**3.9**	**34.1**	**72.8**	**27.4**	**12.2**	**4.6**	**509**
2015ANB 002	**4.1**	**33.9**	**73.0**	**26.2**	**15.8**	**4.8**	**618**
2015ANB 003	4.7	33.2	70.0	25.5	18.3	4.8	498
2015ANB 004	**4.2**	**31.7**	**71.0**	**25.1**	**16.6**	**4.5**	**900**
2015ANB 005	**3.9**	**36.8**	**74.5**	**24.2**	**20.5**	**4.8**	**832**
2015ANB 006	**4.3**	**36.4**	**71.9**	**24.4**	**12.3**	**4.4**	**642**
2015ANB 007	**4.5**	**36.6**	**72.2**	**18.5**	**16.3**	**4.2**	**567**
2015ANB 008	5.3	32.3	70.2	19.4	16.0	4.1	442
2015ANB 009	4.8	33.4	71.2	17.5	16.4	4.7	428
2015ANB 010	**4.1**	**31.9**	**70.4**	**19.6**	**18.2**	**5.1**	**690**
2015ANB 011	**4.5**	**33.3**	**73.2**	**22.8**	**19.8**	**4.8**	**609**
2015ANB 012	**3.9**	**34.0**	**74.3**	**25.4**	**14.5**	**4.7**	**635**
2015ANB 013	6.0	33.5	70.3	16.6	16.7	4.6	432
2015ANB 014	5.2	36.2	71.0	15.2	12.2	3.9	273
2015ANB 015	**3.8**	**36.9**	**72.5**	**27.7**	**22.0**	**4.6**	**725**
2015ANB 016	**4.7**	**37.7**	**72.0**	**24.6**	**14.3**	**3.8**	**618**
2015ANB 017	5.5	33.3	71.7	19.3	20.8	4.2	261
2015ANB 018	5.3	37.4	73.7	19.6	13.7	4.2	497
ADP47	6.3	32.1	70.7	16.4	6.5	3.6	151
ADP48	5.8	35.1	71.6	13.8	12.1	4.4	320
ADP54	5.6	35.8	71.4	19.2	12.0	5.1	158
ADP57	6.4	36.2	71.4	14.9	7.0	5.1	112
ADP93	5.5	35.8	69.9	16.5	9.0	4.5	180
LOCAL CHECK	4.5	32	69.3	20.5	21.0	5.0	496
RAB CHECK	4.7	30.8	70.7	26.1	25.6	4.3	801
P value	<.001	<.001	0.023	<.001	<.001	0.207	<.001
%cv	18.88	6.24	3.38	24.31	40.05	17.13	50.38

Results where ADP lines were evaluated with locally bred materials in 2016, showed that they performed poorly for yield and other agronomic traits (Table 5 and table 6). The best materials included 2015AN004, 2015AN012, 2015AN15, 2015AN011, 2015AN010, 2015AN005 with the mean yield ranging between 1083 and 1449 kg ha-1.

Table 5: Growth data of the five introduced genotypes and local inbred lines evaluated during advanced trials

Genotypes	Angular leaf on leaves spot	Angular leaf spot on pods	Anthracnose on leaves	Ascochyta blight on leaves	Bean common mosaic necrosis virus	Bean common mosaic virus	Common bacterial blight on leaves	Rust on leaves
2015ANB 001	3.5	2.2	1.5	2.3	0.9	2.0	1.0	1.7
2015ANB 002	3.2	2.3	1.5	2.3	1.0	2.3	1.0	1.9
2015ANB 003	3.8	2.3	1. 7	2.0	1.0	3.3	1.0	1.5
2015ANB 004	3.5	2.5	1. 7	2.2	1	2.2	1.0	1.5
2015ANB 005	3.1	3.1	1.5	2.6	1.9	2.2	1.4	1.6
2015ANB 006	3.1	2.3	1.5	2.8	1.1	2.0	1.0	2.4
2015ANB 007	3.4	2.4	1.5	2.1	1.2	2.3	1.0	1.4
2015ANB 008	3.8	1.8	1.4	2.5	1.3	3.3	1.0	1.7
2015ANB 009	3.6	2.3	1.5	2.1	1.5	2.8	1.0	1.7
2015ANB 010	3.3	2.8	1.5	2.2	2.3	2.5	1.7	1.6
2015ANB 011	3.9	2.2	1.5	2.1	1.8	2.7	1.6	2.0
2015ANB 012	2.9	1.9	1.5	2.2	1.1	2.2	1.0	2.2
2015ANB 013	3.3	2.0	1.7	2.2	1.2	3.0	1.5	1.7
2015ANB 014	3.3	2.2	1.5	2.0	1.7	2.5	1.1	1.6
2015ANB 015	3.2	2.1	1.6	2.5	1.0	2.9	1.0	1.8
2015ANB 016	3.3	2.5	1.7	3.0	1.0	2.8	1.0	1.5
2015ANB 017	3.3	2.2	1.8	2.3	1.3	3.3	1.0	1.7
2015ANB 018	2.9	2.7	1.5	2.0	1.0	2.3	1.0	1.7
ADP47	3.3	2.9	2.1	2.1	1.0	5.4	2.3	2.9
ADP48	3.3	2.7	2.0	2.1	0.9	4.4	1.0	1.7
ADP54	3.4	2.7	2.2	2.4	1.2	4.4	1.4	3.3
ADP57	4.2	2.5	1.8	2.2	1.3	5.2	1.0	1.5
ADP93	3.5	3.3	1.7	2.0	1.5	4.2	1.0	1.8
LOCAL CHECK	4.2	3.2	1.8	2.7	2.5	6.3	1.0	2.0
RAB CHECK	4.3	2	1.7	2.2	1	3.0	1.0	1.5
P value	**0.116**	**0.009**	**0.012**	**0.474**	**0.006**	**<.001**	**0.287**	**<.001**
%cv	**21.87**	**27.29**	**21.48**	**27.69**	**55.4**	**32.16**	**57.44**	**35.75**

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Table 6: Mean yield of ADPs evaluated along with locally bred materials in 2016

SN	Entry	Pedigree	Yield kg ha^{-1}
6	**2015AN004**	**RWR 1668 X SMC 21 F3-1-3-1**	**1,449**
17	**2015AN012**	**KAB 06F2-8-27 X RWR 2076 (2)**	**1,333**
22	**2015AN15**	**KAB 06F2-8-27 X RWR 2076(FM)**	**1,241**
16	**2015AN011**	**RWR 1668 X SMC 21 F3-1-3-7**	**1,191**
15	**2015AN010**	**RWR 2245 X RWR 2154**	**1,170**
7	**2015AN005**	**RWR 2154 X RWR 1668 F3-1-1-3**	**1,083**
11	RAB CHECK	RWR 2245	1,076
10	2015AN007	RWR 2154X SMC 16 F3-2-2-8	1,057
2	2015AN002	RWR 2076 X KAB06F2-8- 27	1,031
4	2015AN003	RWR 2154X RWR 1668F3-1-1-3	1,027
14	2015AN009	RWR 2245 X RWR 2154 F 3-2-9	875
5	LOCAL CHECK	Mixture	821
1	2015AN001	KAB 06F2-8-27 X RWR 2076 (1)	794
9	2015AN006	KAB 06F2-8-27 X RWR 2154	747
23	2015AN16	NUA 99 X RWR 2076	685
25	2015AN18	RWR 2076 X CAL 96	603
13	2015AN008	RWR 2245 X RWR 2154 F 3-2-9	594
21	ADP48	Unknown	540
18	2015AN013	RWR 1668 X SMC 21 F3-1-3-15	521
8	ADP54	Unknown	457
24	2015AN17	RWR 2154 X RWR 1668 F3-1-1-10	411
20	2015AN014	RWR 2245X RWR 2154F3-1-3-8	382
3	ADP47	Msolini	345
19	ADP93	Moro	281
12	ADP57	Kijivu	170

Lines Introduced from MSU

Among the 252 genotypes introduced from MSU, only 15 were found to be resistant (Table 7), 115 were tolerant (Appendix 1) and 122 were susceptible to Root rot disease complex (Appendix 2). However, yield data was not collected because two months later after planting, all plants were completely destroyed due to various factors including bean fly, drought stress, poor soil fertility and high soil acidity. Tables on tolerant and susceptible genotypes are attached as appendices.

Table 7: List of sixteen introduced bean varieties that were resistant to root rot disease complex

Resistant (1)			
RWR 2245	G11404	NE34-12-33	B11553
N11257	G11463	NABL6	B11591
N12453	K11916	NABL 20	B11598
N12466	NE34-12-5	B11514	B11606

4. DISCUSSION

Preliminary trial results of ADPs lines

Seventy-six candidate lines were selected for future intermediate trials out of the 300 introduced genotypes evaluated. Significant differences were observed between genotypes in terms of plant vigor (P<0.001), pod efficiency (P=0.007) and yield (P<0.01) (Table 2a, b, c, d). The average yield ranged from near zero for ADP114 to 1612 kg ha-1 for ADP282. Compared to the control RWR 2245 (1076 kg ha-1), sixteen genotypes had higher yields. No significant difference (P>0.05) was observed for Angular leaf spot, Anthracnose, Ascochyta blight and bean rust disease. However, for BCMNV and BCMV there was significant difference (P< 0.05). Root rot evaluation under field conditions was done at Rubona, where out of 76 entries evaluated in 2015B in 3 replications, the entries including ADP666, ADP103, ADP50, ADP44, ADP6, ADP214, ADP52, ADP61, ADP54, ADP39, ADP57, ADP211 performed better with high resistance than the rest of evaluated entries. At Akanyirandori, all evaluated lines were susceptible to bean fly where the whole nursery was 100% destroyed. GEI is differential phenotypic performance of genetically uniform genotypes across test environments. It occurs in different crops including maize, cucumber (Mahendra et al., 2018), rice (Shilai Zhang *et al.*, 2017), maize (Li *et al*., 2018). Ali *et al*., (2003) reported that the phenotypic performance of a genotype is not necessarily the same under diverse agroecological conditions. He reported also that genotypes may perform well in particular environments, but may yield poorly in several

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other locations. Nazrul and Shaheb, (2016) reported that all the local French bean lines performed better and produced higher seed yields compared to non-locally developed varieties. The results in this study are in line with findings of Mukankusi (2008) who observed none of the forty-four tested genotypes were resistance or immune to the root rot disease. Mukankusi *et al*. (2010) reported the substantial variation in resistance to Fusarium root rot. Effects of differences in the screening environment suggest the need to identify resistance in the predominant environment from the targeted areas (Mukankusi *et al*., 2010). Significant differences among tested varieties were observed elsewhere (Habte, 2018).

Among the 76 genotypes evaluated during intermediate trial, 5 genotypes were selected based on yield performance for further evaluation in advanced yield trials. The selected genotypes are ADP47, ADP-48, ADP53, ADP57 and ADP93 all having less yield compared to local check. The present study is in agreement with Wahome (2011) who reported that multiple disease resistant lines were not the highest yielders.

Only ADP48 was kept for its performance which is twice more than the other ADP lines but less than locally developed lines. The best yielding materials including 2015AN004, 2015AN012, 2015AN15, 2015AN011, 2015AN010, 2015AN005 with the mean yield ranging between 1083 and 1449 kg ha-1. According to Frey (1964) a variety having wide or good adaptability is one that consistently gives superior performance over several environments.

Wagara and Kimani (2007) reported that some of the nutrient rich bean varieties possess good levels of resistance to diseases and their adoption would increase bean production and improve human health (Wagara and Kimani, 2007). Availability of tolerant or resistant to bean root rot diseases is of great importance in national breeding programs (Namayanja, 2015) since the problem of declining soil fertility is on the increase in the Great Lakes region and consequently will result in an outbreak of bean root rot diseases.

The observed complete destruction of some nurseries was due to various factors including bean fly, drought stress, poor soil fertility and high soil acidity. Though considerable progress has been made in bean improvement for root rot diseases, it is essential that the work continues. Factors such as bean variety, cultivation method, planting date, previous crop, soil physical characteristics, seasonal patterns and fertilizers use are associated with the occurrence of Fusarium oxysporum in the soil (Naseria and Tabande, 2017). Yield losses due to diseases were observed in other studies (Mongi *et al*., 2018) where significant decrease in yield and yield related parameters was observed due to angular leaf spot disease with influence of the cultivar. This is in agreement with Macedo *et al*. (2017) who reported that understanding disease risk in an evolutionary context should support breeding and selection for resistance and strategies for root rot management in common bean.

5.CONCLUSION

The results support the superior performance of locally bred materials over the introduced lines. The value of introduced lines such as the ADP panel is to identify individuals with specific traits of economic value that might be lacking in local lines. The identification of 16 lines with resistance to local isolates of root rot provides breeders with the needed genetic variability to introduce resistance into locally adapted lines. The overall disappointing performance of the ADP lines is not a surprise as these represent varieties and landraces from other continents and production areas that are not adapted to local conditions in Rwanda but again may possess valuable traits that could be exploited in local breeding programs. Understanding disease risk in an evolutionary context should support breeding and selection for resistance and strategies for root rot management in common bean. Breeding for bean fly the availability of resistant genotypes among the tested materials with resistant or immunity to the root rot diseases are the issues that should be given attention in a national breeding program. Identification of resistance in the predominant environment from the targeted areas is of great importance. Though the majority of introduced lines performed poorly compared to the rest of tested entries some of the nutrient rich bean varieties including 2015AN004, 2015AN012, 2015AN15, 2015AN011, 2015AN010, and 2015AN005 possessed good levels of resistance to diseases and their adoption in different agro ecological zones of the country would increase bean production and improve human health in Rwanda.

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REFERENCES

1. Abawi and Ludwig, 2005, Effect of Three Crop Rotations With and Without Deep Plowing on Root Rot Severity and Yield of Beans, Annual report, Bean Improvement Cooperative. 48:118-119.

2. Ali, N.F., Javidfar, N.F. and Mirza, Y. 2003. Selection of stable rapeseed (Brassica napus L.) genotypes through regression analysis. Pak. Journal of Botany. 35:175-183.

3. Buruchara, R.A. and G. Rusuku. 1992. Root rots in the Great Lakes Region. Proceedings of the Pan-African Bean Pathology Working Group Meeting, Thika, Kenya, May 26-30, 1992. CIAT Workshop Series No. 23. International Center for Tropical Agriculture (CIAT), Kampala, Uganda.

4. CIAT, 2012 Trait Dictionaries for Fieldbook Development" at http://mbp.generationcp.org and http://www.cropontology-curationtool.org/.),

5. Cichy, K.A., T. Porch, J.S. Beaver, P. Cregan, D. Fourie, R. Glahn, M. Grusak, K. Kamfwa, D. Katuuramu, P. McClean, E. Mndolwa, S. Nchimbi-Msolla, M.A. Pastor-Corrales,

and P.N. Miklas. (2015). A Phaseolus vulgaris diversity panel for Andean bean improvement. Crop Science 55: 2149–2160.

6. Food and Agriculture Organization (FAO) of the United Nations, 2018, Decline in crop yields, FAO report available at:http://www.fao.org/docrep/v4710e/V4710E05.htm Accessed January 2018

7. Frey K.I, 1964. Adaptation reaction of oat strains selected under stress and non- stress environmental conditions, Crop Science 4: 55-58.

8. Habte U, 2018. Evaluation of Adaptability of Mung Bean Varieties in Moisture Stress of Eastern Harerghe Zone, Agri Res & Tech: Open Access J. 2018; 13(2): 555880. doi: 10.19080/ARTOAJ.2018.13.555880

9. Kajumula Sixbert Mourice and George Muhamba Tryphone, 2012, Evaluation of Common Bean (Phaseolus vulgaris L.) Genotypes for Adaptation to Low Phosphorus, International Scholarly Research Network ISRN Agronomy Volume 2012, Article ID 309614, 9 pages doi:10.5402/2012/309614

10. Kalyebara M. R., Andima Dymphina, Roger Kirkby and Robin Buruchara. 2008. lmproved Bean Varieties and Cultivation Practices in Eastern-Central Africa: Economic and Social Benefits. Centro Internacional de Agricultura Tropical- CIAT. Cali, Colombia.

11. Katungi E., A.Farrow, T. Mutuoki, S.Gebeyehu, D.Karanja, F.Alamayehu, L.Sperling, S.Beebe, J.C. Rubyogo and R. Buruchara. 2010. Improving common bean productivity: An Analysis of socioeconomic factors in Ethiopia and Eastern Kenya. Baseline Report Tropical legumes II. Centro Internacional de Agricultura Tropical - CIAT. Cali, Colombia

12. Katungi Enid, Catherine Larochelle, Josephat Mugabo, and Robin Buruchara, 2016, Estimating the impact of climbing bean adoption on bean productivity in Rwanda: Endogenous Switching Regression., Invited paper presented at the 5th International Conference of the African Association of Agricultural Economists, September 23-26, 2016, Addis Ababa, Ethiopia.

13. Kseniia Mikova, Enock Makupa, John Kayumba, 2015. Effect of Climate Change on Crop Production in Rwanda. Earth Sciences. Vol. 4, No. 3, pp. 120-128. doi: 10.11648/j.earth.20150403.15. Larochelle C, A. J. (2014). Impact of improved bean varieties on food security in Rwanda; Impact of bean research in Rwanda and Uganda. Independent Science and Partnership Council Secretariat, standing panel on impact assessment, Rome, 2014. .

14. Larochelle Catherine, Dorene Asare-Marfo, Ekin Birol and Jeffrey Alwang. (2016). Assessing the adoption of improved bean varieties in Rwanda and the role of varietal attributes in adoption decisions. CIAT-HarvestPlus report.

15. Li Z, Coffey L, Garfin J, Miller ND, White MR, Spalding EP, de Leon N, Kaeppler SM, Schnable PS, Springer NM, Hirsch CN, 2018, Genotype-by-environment interactions affecting heterosis in maize, PLoS One.2018 Jan 17;13(1):e0191321. doi: 10.1371/journal.pone.0191321

16. Macedo R, Sales LP, Yoshida F, SilvaAbud LL, Lobo M, Junior (2017) Potential worldwide distribution of Fusarium dry root rot in common beans based on the optimal environment for disease occurrence. PLoS ONE 12(11): e0187770. https://doi.org/10.1371/journal. pone.0187770

17. Mahendra Dia, Todd C. Wehner Gary W. Elmstrom, August Gabert, James E. Motes, Jack E. Staub, Greg E. Tolla, and Irvin E. Widders, 2018, Genotype X Environment Interaction for Yield of Pickling Cucumber in 24 U.S. Environments, Open Agriculture, 3: 1–16.

18. Mongi Rose, Pangirayi Tongoona, Hussein Shimelis, and Julia Sibiya, 2018, Agronomic performance and economics of yield loss associated with angular leaf spot disease of common bean in the Southern Highlands of Tanzania, Plant Disease, 102 (1): 85-90

19. Mukankusi Clare 2008, Improving resistance to Fusarium root rot (Fusarium solani (Mart.) Sacc. f. sp. phaseoli (Burkholder) W.C. Snyder & H.N. Hans, A thesis submitted in fulfilment of the academic requirements for the degree of Doctor of Philosophy In Plant Breeding, Faculty of Science and Agriculture School of Biochemistry, Genetics, Microbiology and Plant Pathology University of KwaZulu-Natal, Pietermaritzburg, South Africa, 201pp

20. Mukankusi M. Clare, Rob Melis, John Derera , Mark Laing and Robin A. Buruchara, 2010, Identification of sources of resistance to Fusarium root rot among selected common bean lines in Uganda, Journal of Animal & Plant Sciences, 2010. Vol. 7, Issue 3: 876- 891. http://www.biosciences.elewa.org/JAPS; ISSN 2071 - 7024

21. Namayanja Annet, 2015, Mechanism of inheritance of resistance to Pythium root rot disease and traits for tolerance to low soil fertility in common bean, a thesis submitted in fulfillment of the requirements for the degree of doctor of philosophy in crop science and production of Sokoine University of Agriculture. Morogoro, Tanzania, pp153

22. Namugwanya M, Tenywa JS, Otabbong E, Mubiru DN, Masamba TA (2014) Development of common bean (Phaseolus vulgaris L.) production under low soil phosphorus and drought in sub-Saharan Africa: a review. Journal of Sustainable Development; Vol. 7, No. 5; 2014 ISSN 1913-9063 E-ISSN 1913-9071

23. Naseria Bita and Leila Tabande, 2017, Patterns of Fusarium wilt epidemics and bean production determined according to a large-scale dataset from agro-ecosystems, Rhizosphere 3:100–104.

24. Nazrul M.I. and M.R.Shaheb 2016, Performance of French bean (Phaseolus Vulgris) genotypes in Sylhet Region of Bangladesh, Bangladesh Agron. J. 2016, 19(1): 37-44

25. Nzungize John Rusagara, François LyumugabeE, Jean-Pierre Busogoro and Jean-Pierre Baudoin (2012). Pythium root rot of common bean: biology and control methods. A review. Biotechnol. Agron. Soc. Environ. 16(3): 405-413.

26. Richardson, K.V. (2011). Evaluation of four green bean varieties (Phaseolus vulgaris L) for pest and disease tolerance. GRAC Crop Research Report No.7, Department of Agriculture, Nassau, Bahamas.

27. Rodríguez De Luque, Jesús José; Creamer, Bernado. 2014. Major constraints and trends for common bean production and commercialization; establishing priorities for future research = Principales restricciones y tendencias en la producción y comercialización de fríjol común; estableciendo prioridades de investigación. Agronomía Colombiana 32(3): 423-431.

28. Sebuwufu Gerald, Robert Mazur, Michael Ugen, Mark Westgate 2015, Using improved varieties and fertility enhancements for increasing yield of common beans (Phaseolus vulgaris L.) grown by small-landholder farmers in Uganda, African Journal of Agricultural research, 10(52):4795-4805.

https://doi.org/10.5897/AJAR2015.9638

29. ShilaiZhang, JianHu, ChundaoYang, HaitaoLiu, FengYang, JihuaZhou, Ben K.Samson, ChanthakhoneBoualaphanh, LiyuHuang, GuangfuHuang, JingZhang, WanqiHuang, DayunTao, DomeHarnpichitvitaya, Len J.Wade, FengyiHu, 2017, Genotype by environment interactions for grain yield of perennial rice derivatives (Oryza sativa L./Oryza longistaminata) in southern China and Laos, Field Crops Research, 207:62-70.

30. Trait Dictionaries for Fieldbook Development" at http://mbp.generationcp.org and http://www.cropontology-curationtool.org

31. Wagara N and P.M Kimani, 2007, Resistance of nutrient-rich bean varieties to major biotic constraints in Kenya, African Crop Science Conference Proceedings. 8:2087-2090.

32. Wahome S.W, P.M. Kimani, J.W. Muthoni, R.D. Narla and R. Buruchara, 2011, Multiple Disease Resistance in Snap Bean Genotypes in Kenya, African Crop Science Journal. 19(4):289 – 302.

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Appendix1: List of introduced bean varieties that were tolerant to root rot disease

Tolerant (2-3)			
C12911	G05922	B11550	B11613
N11277	G09303	B11556	B11614
N11238	K11914	B11558	B11615
N11298	K11917	B11562	B11617
N11256	NE34-12-1	B11563	B11618
N11251	NE34-12-2	B11564	B11619
N11225	NE34-12-3	B11571	B11621
N12468	NE34-12-4	B11572	MIB 465
N12442	NE34-12-26	NE34-12-13	B11519
N12447	NE34-12-27	NE34-12-36	B11522
N12441	K131	NE34-12-37	B11523
NE34-12-7	1920020	B11585	B11524
NE34-12-8	RAA	B11587	B11525
NE34-12-9	NE34-12-49	B11588	B11526
NE34-12-10	NE34-12-23	B11589	B11509
N11228	NE34-12-48	B11590	B11510
N12461	ACC110149	B11592	B11511
N12458	ACC108268	B11593	B11516
N12456	ACC101212	B11594	B11502
N12446	NE34-12-6	B11595	B11503
N12454	B11567	B11596	B11504
N12440	B11568	B11597	B11513
G 111466	B11527	B11599	NE34-12-47
G11464	B11528	B11600	NE34-12-39
G11420	B11529	B11601	NE34-12-32
G12508	B11530	B11604	NE34-12-29
G12901	B11531	B11609	NE34-12-15
G12902	B11541	B11610	ACC11272/10,PR1147-6
G12904	B11549	B11612	

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Appendix 2: List of introduced bean varieties that were susceptible root rot disease

Susceptible (4-5)			
S11703	N11226	N12467	NE34-12-45
P07863	1089580	Awash Melk	NE34-12-46
PO9425	MBC29685	N084-12-39	B11575
P12610	112310	INE 34-12-42	B11576
P11506	1089020	E 34-12-50	B11578
P12603	K11939	ACC109 1291	B11579
P08161	K11915	RL2550me	B11581
C11260	K11918	NE34-12-10	B11582
C11273	G12903	NE34-12-12	B11584
C06808	GO 8254	NE34-12-34	B11603
C1266	G93414	NE34-12-35	B11616
C99833	K11919	B11532	B11620
P04205	K08961	B11534	B11622
K131	K12803	B11535	B11623
512910	K1280	B11536	B11624
508418	K11926	B11539	NABE2
500809	K12801	B11542	B11565
NABE20	K12805	B11543	B11566
G11431	K12811	B11544	B11517
K90909	K12807	B11545	B11518
R11608	K12802	B11547	B11515
R19633	K12866	B11548	B11512
R11604	ACC611625	B11552	B11505
R12859	ACC82054/10,PUEBLA	B11554	NE34-12-38
R12832	ACC804554/10	B11555	NE34-12-31
R98026	NE34-12-17	B11557	NE34-12-30
I 11271	NE34-12-18	B11559	NE34-12-28
3G11464	NE34-12-21	B11569	NE34-12-14
RWR 719	NE34-12-22	B11570	
N11284	NE34-12-24	B11573	
N11230	NE34-12-25	B11574	