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Yield stability of some bush snap bean genotypes in Uganda

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Research Paper

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Pod yield stability was studied on fourteen snap bean genotypes introduced or locally bred in Uganda. The study was carried out in three seasons using six agro-ecological zones. All the six non commercial genotypes had been gene pyramided for rust, Angular leaf spot and common bacterial blight making them tolerant to the diseases. J12 had the highest yields and the commercial variety Paulista had the lowest. Values of *bi* coefficient indicated that varieties had the highest positive influence on pod yields while location and season had higher negative influence than rust. Variety J 12 and SB001 had the most stable and heavy pod yields Population dynamics showed that Paulista and Angela had the most unstable plus lowest yields.

Key words: Snap beans, genotypes yield stability, pests and diseases, coefficients of variation

INTRODUCTION

Snap bean (*Phaseolus vulgaris* L.), also called French or green bean, is of primary importance not only as a source of income, but also as a nutrition (Snap beans are rich in micronutrients: vitamin A, folic acid, Mg and Ca) and food security crop among the smallholder farmers in East and Central Africa (ECA) region. It is the number one export horticultural crop in Kenya, contributing an average of 18% value of all horticultural export crops in the country (HCDA, 2009). In Rwanda, snap beans led other horticultural crops in income generation, which was estimated to vary from US$ 400 to 1,000 per producer.

While production and trade statistics are less precise, the importance of snap beans is growing rapidly in Uganda and other countries in the region (Kimani, 2006). The crop (together with dry beans) was ranked among the top priority pulses of the High Value Non-Staple Crops Program (HVNSCP) of the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA).

Snap bean is a labour intensive crop that employs mostly the youth and women with a good balance in gender roles in the physical production and trade operations. However, the major management decisions along the production to market value chain are dominated by men or by both men and women. In Rwanda, for example, 65% of the producers and 95% of the traders were below 42 years of age, while 90% of the management decisions were attributed to men alone or both men and women, and 10% by women alone. However, 80% of the field production chores were done either by men or women, while retail trade in 76% of the cases was dominated by women. The participation of men in snap bean production was attributed to the attractive high returns from snap bean. However, this adversely affected the access to household income by women and youth.

The low pod yields reported in ECA are partly due to diseases, pests and unavailability of high yielding varieties resistant to major diseases. Most of the available varieties are highly susceptible to rust, angular leaf spot, anthracnose (Kimani, 2006) and common bacterial blight (Musaana et al., 2011; Katafire et al., 2011). Farmers rely heavily on pesticides to control these diseases (Otim et al., 2011; Nderitu et al., 2007). This increases the risk of *rejection* of their produce should the chemical content exceed the acceptable maximum residue levels in export markets (Odong, 2011). Furthermore reliance on expensive pesticides reduces the profitability of the crop and exposes farmers to *toxic pesticides* and adversely affects the environment. Current production of snap beans is based on expensive seed of *imported* varieties, which are often *poorly adapted* to local conditions. Most of these varieties are *patented* and therefore not freely accessible to the small scale farmers. The farmers who grow seeds of the patented varieties without contracts, risk potentially devastating legal penalties and loss of market opportunities. To reduce the impact of these practices and improve profitability of snap bean enterprises, ASARECA and Central Internacional de Agricultura Tropical (CIAT) has facilitated ECA countries to develop snap bean varieties with multiple resistances to rust, angular leaf spot, common bacterial blight and anthracnose, acceptable pod traits and high yield potential.

In Uganda, six advanced bush and climbing bean lines with multiple resistance to rust, angular leaf spot and common bacterial blight were selected (Musaana et al., 2011). Validation of the performance of the selections compared to the commercial imported lines was found necessary to determine best performing lines in the country, value for cultivation and use especially shelf life, consumer acceptability, pod traits and identify new candidate varieties for formal release. This will facilitate local production using these locally bred lines that are not patented plus dissemination of certified seed.

LITERATURE REVIEW

Marker assisted breeding has been used to pyramid resistance in beans to multiple diseases (Jung et al., 1996; Myers, 2000; Myers and Baggett, 1999; Pastor-Corrales and Airme, 2004). Some of the genes for common bacterial blight were originally found in wild relatives of the beans, resulting in inter-specific hybridization (McElroy, 1985; Park and Dhanvantari, 1987; Pastor-Corrales et al., 2004). The Snap bean germplasm available in the ECA countries was first pyramided for multiple diseases in CIAT then continued in individual countries, Some of the germplasm developed in Kenya and Rwanda was received in Uganda for more improvement or screened for direct use (Kimani et al., 2004; Musaana et al., 2011; Musoni 2012)

Snap beans have been categorized among the high input crops for a long time by farmers in Uganda due to the high requirements of chemical pesticides and imported seeds. Due to the very many diseases that attack the crop, single disease resistances began as early as the late eighties (Silbernagel, 1986) until an approach of multiple disease resistance was initiated by CIAT (Miklas et al., 1994; Musaana at al., 1994). Often times crops that are bred and tested in environments that are not the same as the target country end up performing poorly due to lack of adaptation (Wortman et al. 1996). This makes it important for local and multilocational testing to take place in the country that intends to grow the crop.

During the development and selection of genotypes diverse environments are used for the purposes of identifying the most stable genotype under the different conditions. The most productive and stable genotype say under high disease infection and in different locations would indirectly indicate that the said genotype is resistant to the diseases and therefore would suffer less production losses. A genotype is said to be stable if its response to different environments is parallel to the mean response of all the genotypes in the trial. According to Becker and Leon, (1988) the concept is called the dynamic or agronomic concept of stability. In this case the genotype will performs in the same way under different environmental conditions. This type of stability is static and is seen as biological concept of stability. Genotypes that show high biological stability perform well in different environments.

Differences in performance of genotypes in different environments gave rise to the concept of genotype environmental interaction (G X E). Plant breeders use G X E interactions in the identification and selection of superior genotypes for general or specific adaption to environments. The best method used to analyze for G X E interaction is the analysis of stability of a genotype. Stability of genotypes has been reported to be the most important factor to consider before a variety is released. Yield stability analysis mainly involves the use of linear regression as proposed by Yates and Cochran, (1938) and subsequently modified by Finlay and Wilkinson, (1963). The genotype grouping technique based on coefficient of variation (C.V) and mean yield of Francis and Kannenberg, (1978) has also been used to evaluate genotypes for stability. All these methods are grouped under the univariate statistical methods of assessing stability.

The selection of most productive and stable genotypes in a disease infested environment is an indirect form of accessing the disease resistance of cultivars and lines. In this situation, resistance is seen as a protection against production loss, from the point of view, that resistant cultivars and lines would be the most productive and stable and therefore, presenting a lower yield loss.

This study was therefore conducted with the objectives of among others:
(i) To evaluate the influence of seasons and locations on yield of snap bean genotypes. (ii) To identify genotypes with high stability for yield and propose them for release.

MATERIALS AND METHODS

Fourteen Snap bush bean varieties were planted on station at NaCRRI, BuZARDI, AbiZARDI, NgeZARDI, Kamenyamigo DATIC and Nakabango during the 2012a, 2012b and 2013a seasons. The pedigrees for the six lines were as follows.
1. HAV 129 x G 17723 XG 685 XASC 73 XICTAHUNAPU FIFI. F 5/ 2P-2P-4P inp (SB 001)
2. HAV 129 x G 17723 XG 685 XASC 73 XICTAHUNAPU FIFI. F 5 /3P-6P-1P-inp (SB 002)
3. HAV 129 x G 17723 XG 685 XASC 73 XICTAHUNAPU FIFI. F 5 /2P-2P-5P-inp (SB 003)
4. HAV 129 x G 17723 XG 685 XASC 73 XICTAHUNAPU FIFI. F 5 /2P-1P-2P-inp (SB 004)
5. HAV 129 x G 17723 XG 685 XASC 73 XICTAHUNAPU FIFI. F 5/5P-5P-2P-mp x Paulista x A 20 (NAROSn Be2)
6. HAV 129 x G 17723 XG 685 XASC 73 XICTAHUNAPU FIFI. F 5/3P-3P-1P-mp x Paulista (NARObeSn 1) J12.

Entries 5 and 6 above were backcrossed to Paulista at Kawanda to improve on the pod characters, then entry 5 was crossed with J 12 to improve on the yield of the resulting selection. In addition to the six test lines above, eight commercial varieties were planted to compare their yields with the six test lines. These were Paulista, Serengeti, Andante, Mara, Konza, Angela, Tana and Star.

A randomized complete block design was used with three replicates plus a plot size of 5m x 5m with a spacing of 30cm x 10cm.

Data was recorded for germination, growth habit and vigour one month after germination. Other characteristics plus disease and pest data were recorded at R6 (flowering), R7 (pod formation) and R8 (pod maturity) stages of the plant growth.

Four diseases were evaluated for at all the sites, viz: Rust (*Uromyces appendiculatus* var. *appendiculatus*) Angular leaf spot (ALS), Flowery leaf spot (Fls) and Common Bacterial Blight (*Xanthomonas campestris* pv. *Phaseoli).*All the diseases developed in a similar way in that there was less disease at R6 and susceptibility could be determined at R8. Diseases were scored using a scale of 1-9 where 1-3 was resistant, 4-6 tolerant and 7-9 susceptible.

The data was analyzed using an Excel package and later SPSS versions 20 for analysis of variance (ANOVA) and linear regression analysis. The means were tested using a T-test at 5% level of probability. The univariate statistical method was used to access the stability of individual genotypes through linear models, regression analysis and multivariate analysis using SPSS version 20 and Genstat (Aastveit and Aastveit, 1984) plate 1.

RESULTS AND DISCUSSION

Pod yields

The data was pooled over all the varieties and locations to see if there were any differences between variables. Genotype yield data was pooled over locations and seasons and is presented in (Table 1).

The test genotypes SB001, SB002, SB003, SB004, NARObeSn 2 and NARObeSn 1 had generally stable mean yields across all the locations except SB003 at NgeZARDI. The best performing genotype was NARObeSn 2 with a combined mean across all locations of 16128 kg/ha, followed by SB001 (15028kg/ha), SB002 (13916kg/ha), NARObeSn 1 (13906kg/ha), SB004 (13150kg/ha) and lastly SB 003 (11822kg/ha).

Further analysis of the mean values show that the lowest test variety SB004 with a mean of 13150 kg/ha yielded 7361 kg/ha more than the lowest commercial variety Paulista translating to 108.42% higher. However the same test variety yielded only 10.42% higher than the heaviest yielding commercial variety Andante. Likewise the highest yielding test variety NARObeSn2 had yields of 44% above Andante and 137.56%more than Paulista. This meant that the test varieties were better than the commercial varieties used in these trials. According to Francis and Kannenberg (1978) therefore all the test entries gave stable yields over environments because their mean yields were above the overall mean. Similar results were also reported by Becker and Leon (1988).

The CV values for each genotype described the levels of dispersion of the genotype. The higher the CV the greater the dispersion in the genotype. In this case all the genotypes were relatively stable because the percentages were below 20% (Francis and Kannenberg 1978). Similar results were reported for snap bean yields in Kenya and Rwanda (Kimani, 2006; Musoni 2012).

Figure 1 clearly shows the superior performance of NARObeSn2 (12%) followed by NARObeSn1, SB004, Sb002 and SB001 all at 9% of the total. Likewise SB003 and Tana that had 8% each of the total also showed stable yields over environments (Becker and Leon, 1988).

The six test lines significantly out yielded most of the commercial lines except Andante (7%) and Tana (8%) (Figure 1). Graphical presentations of the yields show differences in yields of the different commercial varieties and the test genotypes, further portraying the benefits of the test genotypes.A one way analysis of variance was carried out and the means are presented in (Table 2).

The ANOVA showed that there were significant differences (P<0.001) between the genotypes used in the

Plate 1. Bush and climbing Snap beans at R6 at ABIZARDI.

Table 1. Mean yields across all seasons and locations.

Location	Paulista	Serengeti	Andante	Mara	Konza	Angella	Tana	
NaCRRI	7000	7000	12000	5000	7500	6500	11000	
BuZARDI	6833	8167	12333	7167	8500	7700	12167	
AbiZARDI	6333	9000	12000	8667	8000	7833	12000	
NgeZARDI	4833	6833	9333	5833	7533	7867	9833	
Kamenyamigo	6233	9500	11200	7333	7167	7333	12167	
Nakabango	3500	6667	10333	6000	5833	6500	10000	
Mean	6789	7861	11200	6667	7422	7289	11194	
CV(5%)	4.27	6.50	9.60	5.08	8.19	11.39	10.34	
Location	**Star**	**SB001**	**SB002**	**SB003**	**SB004**	**NARObeSn2**	**NARObeSn1**	**Mean**
NaCRRI	7500	14500	14333	12600	12500	17000	13233	**10547**
BuZARDI	9600	14333	14333	13000	13033	17500	14167	**11345**
AbiZARDI	13167	16667	15333	13500	15033	15500	14700	**11981**
NgeZARDI	6667	13833	13333	9500	11667	14667	10667	**9457**
Kamenyamigo	8333	**18333**	13667	12000	14833	14833	14667	**11257**
Nakabango	6833	12500	12500	10333	11833	16667	16000	9678
Mean	8683	15028	13667	11822	13150	16128	13906	10711
CV(5%)	3.55	7.13	14.26	7.49	8.97	13.47	7.63	

trials. Significant differences were also shown for locations (P<0.001), rust (P<0.01), ALS (P<0.001), CBB (P<0.001), pod yields (P<0.01) and seed yields (P<0.001). However there were no significant differences (P<0.05) between, the seasons and the reaction to thrips.

The results indicated that the varieties, rust, ALS, CBB, pod yield and seed yield were significantly different in different locations and not seasons. They also show that there were locations that were different from each other. Thrips were not an important variable in this case. Similar results to these were reported for snap beans in Uganda (Musaana et al., 2011).

The lack of significance in differences between seasons indicated that the results of one season could be used to predict with reasonable accuracy the yields of the next season.

A t-test was then performed for individual genotypes to see if there was variation within each genotype to warrant selection in different environments. The results were as in (Table 3). When a T test was used to find out the differences between and within genotypes, significant differences (P<0.001) were found within all genotypes. This plus the differences observed among the means made further analysis for yield stability a necessity in order to select the most stable genotypes for release,J12 Nabe Sn 1 Mean (Table 4).

By modeling the regression coefficients it was shown in figure 1 that varieties had the highest positive influence (blue lines) on pod yields than the pests (rust negative orange lines) in this case. In addition it was only rust than

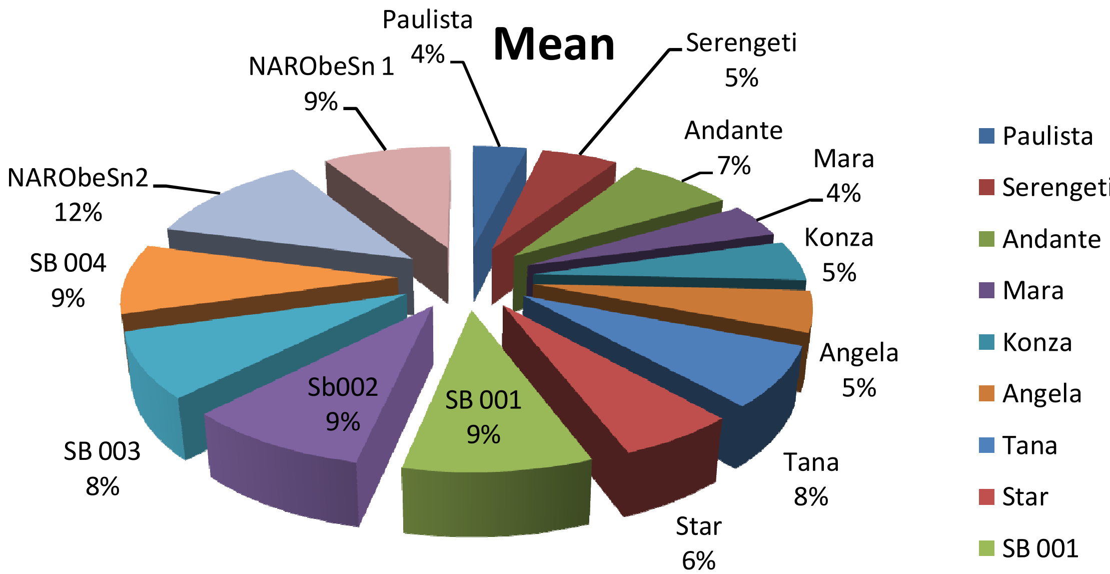

Figure 1. Comparative performance of test and commercial snap bean genotypes.

Table 2. One way Analysis of Variance for the Snap Bean Variables under study.

Variables	Sum of squares	df	Mean square	F	Significance
Varieties	375.96	13	53.71	3.52	.001
Locations	161.81	5	23.12	9.84	.000
Seasons	5.92	2	.85	1.28	.263
Rust	37.14	251	5.31	2.78	.009
ALS	63.18	251	9.03	4.48	.000
CBB	42.39	251	6.06	6.25	.000
Thrips	76.01	251	5.85	1.13	.337
Pod yield	3.42	251	48824490.53	3.24	.003
Seed yield	4.09	251	58498775.12	2.70	.000

Table 3. One-sample t-test.

	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Locations	4.583	5	.006	3.50000	1.5367	5.4633
Paulista	11.068	5	.000	5833.33333	4478.5177	7188.1489
Serengeti	20.611	5	.000	7833.33333	6856.3619	8810.3047
Andante	21.826	5	.000	11416.66667	10072.0506	12761.2827
Mara	12.203	5	.000	7333.33333	5788.6059	8878.0608
Konza	36.200	5	.000	7750.00000	7199.6713	8300.3287
Angella	22.000	5	.000	7333.33333	6476.4727	8190.1939
Tana	30.482	5	.000	11416.66667	10453.8893	12379.4440
Star	5.542	5	.003	9583.33333	5138.1753	14028.4913
SB001	13.975	5	.000	15166.66667	12376.9306	17956.4027
SB002	46.098	5	.000	14166.66667	13376.6802	14956.6531
SB003	19.817	5	.000	12000.00000	10443.4354	13556.5646
SB004	12.185	5	.000	12916.66667	10191.8364	15641.4969
J12	17.330	5	.000	15500.00000	13200.8017	17799.1983
NabeSn1	17.083	5	.000	14250.00000	12105.7074	16394.2926

Table 4. Yield stability parameters for snap bean genotypes.

Genotype	Mean yields kg/ha	Regression coefficient (b_i)	Deviation from regression $S_i^2{}_d$	Shukla's stability variance δ_i^2	Chi square (X^2)
Paulista	6789	1.242	0.01	2.088	6.667
Serengeti	7861	1.078	0.02	0.799	9.556
Andante	11200	-1.817***	-0.04*	2.803	18.444*
Mara	6667	2.388*	0.04	1.661	6.000
Konza	7422	0.186	-0.23*	6.001	12.667
Angella	7289	-0.301*	0.01	0.002	11.556
Tana	11194	-0.832**	-0.11*	3.706	7.667
Star	8683	-1.749***	0.01	3.297	6.444
SB001	15028	-1.318**	0.01	1.729	5.111
SB002	13667	-0.634**	0.01	2.640	10.000
SB003	11882	0.551	0.01	2.888	4.556
SB004	13150	1.615	0.12	4.072	7.556
NARObeSn2	16128	-0.747**	0.01	2.973	8.000
NARObeSn1	13906	0.880	0.01	1.538	4.000

Grand mean 10772,*. **, *** indicate significantly different from unity for the regression coefficient or slope (b_i) and from zero for the deviation from regression ($S_i^2{}_d$) at 0.05, 0.01, 0.001 levels of probability, respectively.

exerted a lot of stress on the genotypes since the other diseases were not shown on the model. The varieties with negative influence are those like Paulista and Angela that were susceptible to rust and ALS. The location with negative influence was Nakabango that had bean fly damage and the season was 2011 b that had drought effects. This made the study to concentrate on varieties, seasons and locations to see which varieties were stable in yields.

The use of a T-test and regression model enabled us to concentrate on a few variables for further analysis of stability since it was only these that influenced the pod yields of the genotypes. Other stresses had negligible influence. The negative locations were cases like Nakabango in 2011b season when there were yield losses due to high infection from the bean fly due to late land preparation and planting.

Location regression lines were drawn over a scatter plot of the pod yields for all the 14 entries (Figure 3). The regression slope was y=662.9x + 6411 and R^2 was 0.932. Outliers were observed on both sides of the regression lines. None of the regression lines had intercepts at zero.

Figure 3 shows the presence of outliers for some of the genotypes which could not be teased out by the univariate analyses and the figures presented above. This proved the need for the use of multivariate analyses to know the stability of individual genotypes. Linear regression lines show that the bottom line is for NgeZARDI followed by Nakabango, Kamenyamigo, BuZARDI and the one at the top is for AbiZARDI.

The regression coefficients or slope (bi) for test lines SB001, SB002 and NARObeSn2 were negative and significant (P<0.01). The values for the rest of the test varieties were positive and non-significant. The deviations from regressions (Si2d) for all the test genotypes were positive and non-significant. Lastly all the values for the test lines for Shula's stability variance were low. The three stability parameters indicate that test entries showed highest stability as follows NARObeSn 1,SB003, SB002, SB001, NARObeSn 2 and lastly SB004.

Pests and diseases

In snap beans it is the pod yield that is of outmost importance. Figure 2 shows that rust had the highest effects on pod yields compared to CBB, ALS and thrips. Further analysis of rust was then carried out to see how it affected pod yields. The results were as in the figures below. None of the varieties was immune to attack by rust. The most susceptible varieties to rust were Paulista and Angela The test entries scored 5 on a score of 1 to 9 indicating that they were tolerant to the disease up to R8.

From the above figures rust reaction on the varieties was very different ranging from susceptible to resistant. The varieties also showed different levels of reaction in different locations due to differences in disease pressure in each

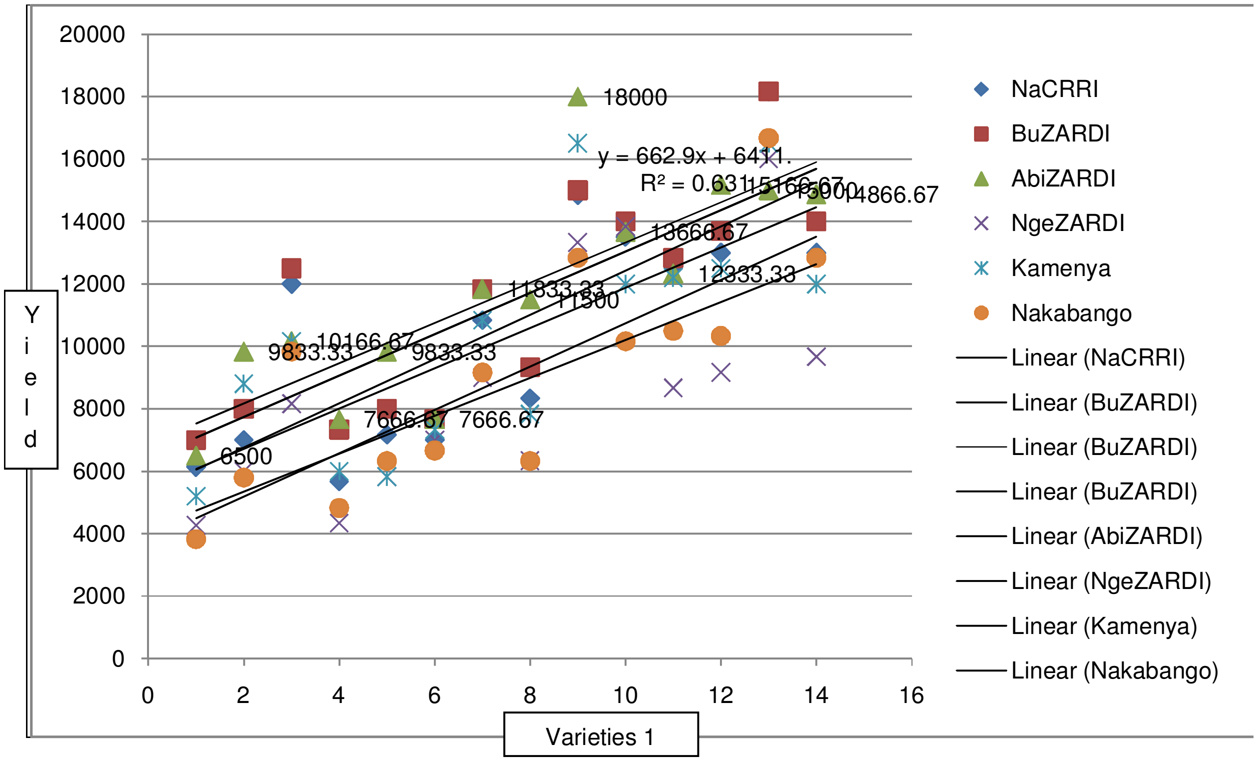

Figure 3. Scatter and linear regression for pod yields of fourteen snap bean genotypes.

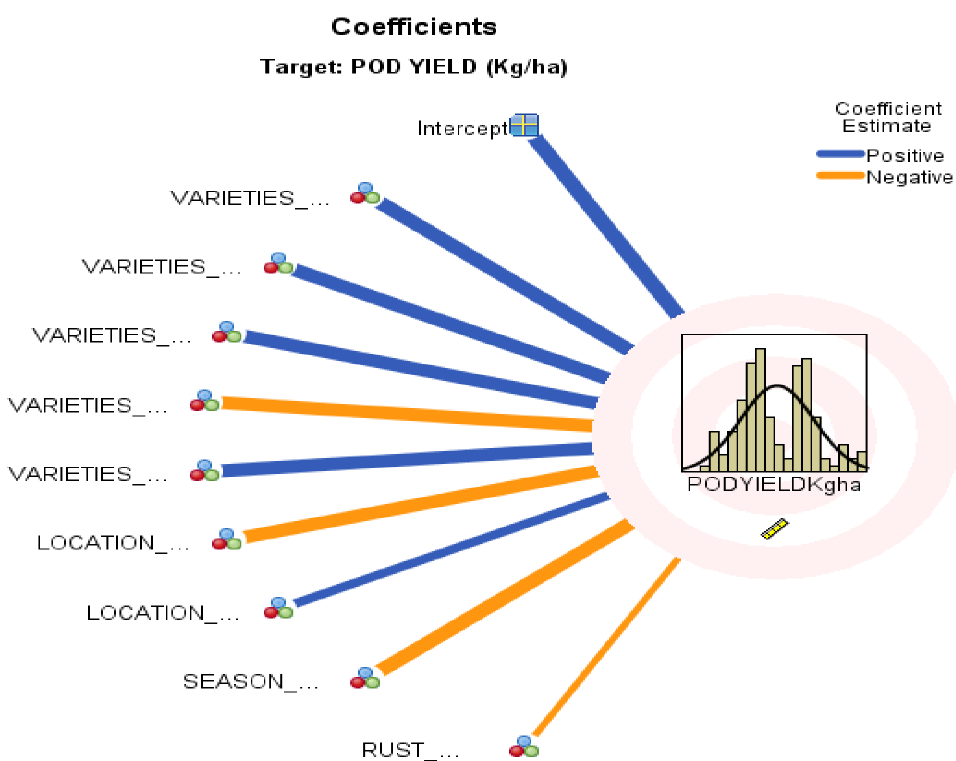

Figure 2. Regression coefficient model for relationships between pod yield and other characters.

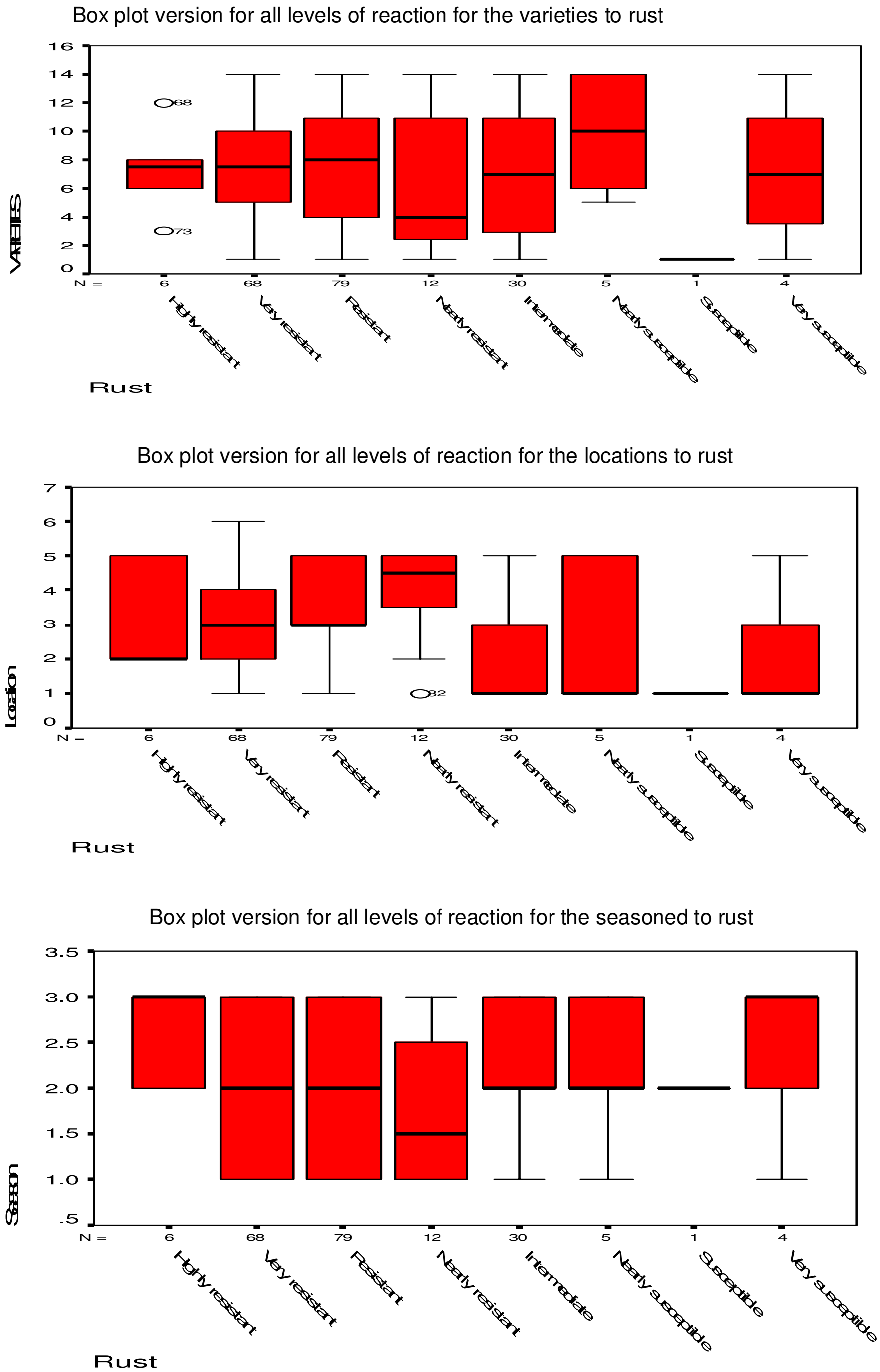

Figure 4. Reaction of the varieties to rust and in different locations plus seasons.

location. The same varietal differences were expressed in the different seasons but the differences were not significant between the test lines.

CONCLUSION

All the six test varieties viz: SB 001, SB 002, SB 003, SB 004, J 12, and Nabe SN 1 had heavy mean yields and were stable across seasons and locations. The varieties are therefore recommended for use by farmers in Uganda and other countries that have similar agro-ecological zone climates like the six locations used in the study. The commercial varieties like. Serengeti, Andante (Extra fine), Mara and Tana are also relatively better in yield stability and can be recommended for use provided farmers buy the seed. However, for the test varieties, farmers had higher preferences for SB 001, SB 004 and J 12.

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