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Research Application Summary

Genetic analysis of resistance to common bean rust disease in Uganda

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Abstract

Bean rust caused by *Uromyces appendiculatus* (Pers., Pers) Unger. is one of the major foliar diseases of common bean in Uganda. In the case of Uganda the framers' preferred cultivars were from the Andean (small-seeded) cultivars which were susceptible to bean rust. Breeding for rust resistance is considered the most economical, practical and effective management option for this disease. The sources of bean rust resistance identified in Uganda were of the Mesoamerican (small-seeded) and Andean (large-seeded) background. However, the combination of both gene pools is often incompatible. This study determined the combining ability of resistant cultivars of both the Mesoamerican and Andean genepool present in Ugandan bean population. Six resistant cultivars were used as males while four cultivars were used as females in a North Carolina II mating design and 18 F_2 families were evaluated for rust disease severity. Results indicated that there was high significant difference ($P<0.01$) among the female and male parents studied for rust disease severity. The parent Redland Pioneer had the lowest negative GCA value (-0.34) and was the best combiner. Conversely, the parent NABE 21 had the highest positive GCA (0.21) and was the lowest combiner. The cross NABE 21x Mexico 309 had the most negative SCA value (-0.59) followed by NABE 16xOuro Negro (-0.43). These particular crosses would be useful in breeding programmes for resistance to bean rust in Uganda.

Key words: GCA, North Carolina II mating design, *Phaseolus vulgaris*, SCA, Uganda

Résumé

La rouille du haricot causée par *Uromyces appendiculatus* (Pers., Pers) Unger. est l'une des principales maladies foliaires du haricot commun en Ouganda. Dans le cas de l'Ouganda les cultivars préférés par les agriculteurs étaient des cultivars andins (à petites graines) qui étaient sensibles à la rouille du haricot. La sélection pour la résistance à la rouille est considérée comme une option de gestion la plus économique, pratique, et efficace pour cette maladie. Les sources de résistance à la rouille du haricot identifié en Ouganda étaient d'origine mésoaméricaine (à petites graines) et andine (à grosses graines). Cependant, la combinaison des deux réserves de gènes est souvent incompatible. Cette étude a déterminé l'aptitude à la combinaison que présentent les deux réserves de gènes des cultivars résistants d'origine mésoaméricaine et andine dans la population de haricots ougandais. Six cultivars résistants ont été utilisés en tant que mâles et quatre cultivars ont été utilisés comme femelles dans un plan d'accouplement de Caroline du Nord II et 18 familles F2 ont été évaluées pour la gravité de la maladie de la rouille. Les résultats ont indiqué qu'il y avait une grande différence significative (P <0,01) chez les parents féminins et masculins étudiés pour la gravité de la maladie de la rouille. Le parent Redland Pioneer avait la plus faible valeur négative d'AGC (-0.34) et il était le meilleur combinateur. Par contre, le parent NABE 21 avait l'AGC positive la plus élevée (0,21) et était le combinateur le plus bas. Le croisement NABE 21x Mexique 309 avait une valeur la plus négative d'ACS (-0,59), suivie par NABE 16xOuro Negro (-0.43). Ces croisements particuliers seraient utiles dans les programmes de sélection pour la résistance à la rouille du haricot en Ouganda.

Mots clés: ACG, conception d'accouplement Caroline du Nord II, *Phaseolus vulgaris*, ACS, Ouganda

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Background

Bean rust caused by *Uromyces appendiculatus* (Pers., Pers) Unger. is one of the major foliar disease of common bean in Uganda (Wortmann *et al.*, 1998). It is known to cause yield losses as high as 100% in susceptible cultivars depending on prevailing conditions (Singh and Schwartz, 2010). The importance of this disease was first reported in Uganda by Atkins (1973) and the need for rust disease management in the country was recently stressed by Odogwu *et al*. (2014). Breeding for rust resistance is considered the most economical, practical and effective management option for this disease (Mmbaga *et al*., 1996; Souza *et al*., 2013).

In Uganda, the farmers prefer common bean cultivars which were of Andean (large-seeded) background because they are agronomically desirable and high yielding but are often susceptible to bean rust (Kiwuka *et al*., 2012; Okii *et al*., 2014; Odogwu *et al*., 2016, unpublished). Odogwu *et al*. (2016, unpublished) identified 15 cultivars with both the Mesoamerican (small-seeded) and Andean (large-seeded) background as sources of rust resistance. Liebenberg (2011) had argued that Mesoamerican germplasm is better for rust resistance and is more suitable for use in Africa, whereas Pastor-Corrales and Steadman (2014) suggested that combining resistance sources of Andean and Mesoamerican origin should provide broad resistance to bean rust. However, Liebenberg (2011) pointed out the incompatibility of crossing large-seeded and small-seeded beans.

Common bean rust resistance is controlled by dominant genes (Souza *et al*., 2013). Indeed Pastor-Corrales and Steadman (2014) reported that resistance to common bean rust is conferred by 10 single, dominant, and independent genes from the Andean (large-seeded) and Mesoamerican (small-seeded) background. However a more durable resistance can be achieved by a combination of both genetic background (Pastor-Corrales and Steadman, 2014).

Combining ability is used to understand the nature of gene action involved in the expression of quantitative and qualitative traits and to predict the performance of the progenies (Machikowa *et al.*, 2011). In the rust resistance breeding program in Uganda, it is very important to know the combining abilities of sources of resistance with the Mesoamerican background with the farmers' preferred cultivars of the Andean background. Therefore, knowledge of combining ability is essential for selection of suitable parents for hybridization and identification of promising hybrids in breeding program (Machikowa *et al.*, 2011). The use of North Carolina (NC) II as a mating design allows a breeder to measure the general combining ability [GCA] and specific combing ability [SCA] (Nduwumuremyi *et al.*, 2013). The design is most adapted to plants that have multiple flowers so that each plant can be used repeatedly as both male and female (Nduwumuremyi *et al.*, 2013). This study focused on determining the combining ability of rust resistant parents from the Andean and Mesoamerican background and the Ugandan Andean susceptible parents.

Study description

Experiments were carried out at the National Crop Resources Research Institute (NACRRI), Namulonge in Wakiso district, Uganda. Six common bean cultivars fully characterized for bean rust resistance were used as male parents while four common bean cultivars fully characterized for tolerant to susceptibility to bean rust were used as female parents (Table 1).

During the first planting season of 2015, staggered planting of the parents was done in order to synchronize flowering dates for easy and successful crossing. The parents were planted in pots in the screen house. At flowering, crosses were made in the screen house using the North Carolina II mating design (Comstock and Robinson, 1952) in which the resistant cultivars acted as the male parents while the susceptible ones as the female parents.

Table 1. Parental common bean cultivars, their pedigree and rust response

Cultivar	Gene pool	Pedigree	Rust response
Female			
NABE 15	Andean	KanyebwaxAB136	Susceptible
NABE 16	Andean	KanyebwaxG2333	Susceptible
NABE19	Andean	K20xG2333	Susceptible
NABE21	Andean	KanyebwaxPI207262	Susceptible
Male			
Ouro Negro	Mesoamerican	NA	Highly Resistant
CNCPI181996	Mesoamerican	CNCxPI181996	Highly Resistant
Mexico 235	Mesoamerican	NA	Resistant
Mexico 309	Mesoamerican	NA	Resistant
Redland Pioneer	Andean	NA	Resistant
CNC	Mesoamerican	Composite of Guatemalan black beans	Resistant

NA: Not available

Subsequently F_1 seed was harvested, dried and planted in the screen house during the second planting season of 2015 for seed multiplication and advancement to F_2. The F_2 seeds were harvested, dried and planted at the onset of the first rains of 2016, in the field using a Complete Randomized Blocking Design (CRBD). Rust inoculation occurred naturally and the cultivar NABE 16 was planted along the boarders as spreader rows to increase rust inoculation. Disease severity was rated using the CIAT 1 to 9 scale by Van Schoonhoven and Pastor-Corrales (1987), where 1-3 = resistant (no visible pustules to few pustules covering 2% of foliar area), 4-6 = intermediate (small pustules covering 5% foliar area to large pustules often surrounded by chlorotic halos covering 10% foliar area) and 7-9 = susceptible (large to very large pustules covering 25% foliar area). The F_2 population used were NABE 15xCNC; NABE 16XCNC; NABE 21XCNC; NABE 15XCNCPI181996; NABE 16x CNCPI181996; NABE 19xCNCPI181996; NABE 21xCNCPI181996; NABE 15xMexico 235; NABE 16x Mex235, NABE 21xMexico 235; NABE 16x Mexico 309; NABE 21xMex 309; NABE 15x Ouro Negro; NABE 16XOuro Negro; NABE 21xOuro Negro; NABE 16xRedland; NABE 19xRedland; and NABE 21xRedland.

Results

The ANOVA for rust severity in the F_2 families is presented in Table 2. There was high significant difference (P<0.01) among the female and male parents. Individual GCA estimates are presented in Table 3. The parent Redland Pioneer had the lowest negative GCA value (-0.34) while the parent NABE 21 had the highest positive GCA (0.21). The SCA estimates are presented in Table 4. The cross NABE 21x Mexico 309 had the most negative SCA value (-0.59) followed by NABE 16xOuro Negro (-0.43) while NABE 21x Ouro Negro (0.57) had the highest positive GCA estimates.

Discussion and conclusion

Negative and lower GCA effect were desirable for rust resistance in this study because it indicated a larger contribution towards resistance while positive values suggested a contribution towards susceptibility (Kiryowa *et al.*, 2008). Since the parent Redland Pioneer had the lowest negative GCA value (-0.34), this implied that Redland Pioneer was the best general combiner for resistance to common bean rust and its use in breeding programmes

Table 2. ANOVA for North Carolina II mating design

Sources of variance	d.f	s.s	m.s	F	ems
Females	3	0.4699	0.1566	2.11014E-14***	0.033821
Males	5	0.4932	0.0986	1.15528E-13***	0.031399
Error	9	1.3224	0.1469	9.63189E-23	0.142496
Total	17	2.2855	0.1344		

df: degree of freedom, ms: Mean square, Values with *** implies significant at P < .001

Table 3. GCA estimates for common bean rust severity on the parents

Parents	GCA estimates
Redland Pioneer	-0.34
NABE 15	-0.15
NABE 19	-0.11
Mex235	-0.10
NABE 16	-0.04
CNCPI181996	0.05
Mex 309	0.09
CNC	0.16
Ouro Negro	0.16
NABE 21	0.21

GCA: General Combining Ability

Table 4. SCA estimates for common bean rust severity of the crosses

Cross	SCA estimates
NABE 21xMex 309	-0.59
NABE 16XOuro Negro	-0.43
NABE 21xCNCPI181996	-0.30
NABE 16xCNC	-0.30
NABE 15x Ouro Negro	-0.15
NABE 16xRedland	-0.11
NABE 16x Mex235	-0.08
NABE 19xCNCPI181996	-0.07
NABE 15xMex 235	-0.07
NABE 16x Redland	0.01
NABE 21xRedland	0.03
NABE 15xCNCPI181996	0.06
NABE 19xRedland	0.08
NABE 21xCNC	0.14
NABE 21xMex235	0.16
NABE 15x CNC	0.16
NABE 16x Mex2309	0.21
NABE 16x CNCPI181996	0.32
NABE 16x Mex309	0.39
NABE 21xOuro Negro	0.57

SCA: Specific Combining Ability

would produce progenies with increased resistance (Kiryowa *et al*., 2008). The reason for this may probably be that the cultivar is of the Andean background (Liebenberg and Pretorius, 2006). The parent NABE 21 with GCA of 0.21 was the worst general combiner because of its highly positive GCA value. If used in hybridization programmes, its progenies would show increased susceptibility to bean rust. Negative SCA effects were also desirable for resistance. The cross NABE 21x Mexico 309 had the most negative SCA value (-0.59) followed by NABE 16xOuro Negro (-0.43). These particular crosses would be useful in breeding programmes for resistance to bean rust (Kiryowa *et al*., 2008).

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