Research Application Summary pp: 515 - 520

Breeding for common bean rust in Uganda

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Abstract

Rust caused by the fungi *Uromyces appendiculatus* is considered as one of the most variable pathogens documented world-wide. In Uganda, rust has been identified as an emerging common bean disease and this has contributed to its being given research current attention and priority. Rust has been known to cause significant yield losses across the bean industry within Africa. It is hypothesized that once this diseases is not given the attention it deserves, it has ability to gravely undermine the potential of common bean as a food security crop for the majority of Ugandans. It is therefore critical that knowledge is generated on the prevalence, genetic and pathogenic diversity, the extent of yield loss and pattern of spread of rust. This review article presents a summary on bean rust research status and development of breeding research in Uganda.

Key words: Common beans, resistance sources, Uganda, *Uromyces appendiculatus*

Résumé

La rouille causée par des champignons *Uromyces appendiculatus* est considérée comme l'un des agents pathogènes les plus variables documentés dans le monde entier. En Ouganda, la rouille a été identifiée comme une maladie du haricot émergents, ce qui a contribué à sa recherche étant donnée l'attention et la priorité actuelle. La rouille est connue pour avoir causé des pertes de rendement importantes dans l'industrie du haricot en Afrique. Il est supposé que, une fois que cette maladie n'est pas donné l'attention qu'il mérite, il a la capacité de nuire gravement le potentiel de haricot commun comme une culture de la sécurité alimentaire pour la majorité des Ougandais. Il est donc essentiel que la connaissance est générée sur la prévalence, la diversité génétique et pathogénique, la mesure de la perte de rendement et le modèle de propagation de la rouille. Cet article de synthèse présente un résumé sur l'état de la recherche sur la rouille du haricot et le développement de la recherche sur la production en Ouganda.

Mots clés: haricots communs, sources de résistance, l'Ouganda, *Uromyces appendiculatus*

Introduction

Dry common bean (*Phaseolus vulgaris* L.) is an important and versatile commodity grown in almost all parts of the populated world and accounts for more than 90% of the cultivated crop in the world (Thiago *et al*., 2013). Citing the FAO statistics of 2006, Gepts *et al.*, (2008) provided an insight into the economic status of common bean (*Phaseolus vulgaris*) throughout the world (http://faostat.fao.org/site/408/default.aspx; verified December 5, 2006). Their report showed that dry beans were grown on 27.7 million hectare of land in 148 countries in 2004 and total production was 18.7 million metric tons (MT). However, recently Thiago *et al*. (2013) reported that the crop is grown and consumed on approximately 30 million hectares in about 120 countries during 2011 (faostat.fao.org). According to the report, '*Phaseolus* beans are the most important grain legume for direct human consumption'. In eastern Africa, it is consumed by people from all income levels and serves as a primary source of dietary protein for people in the lower income bracket (Sibiko, 2012) and the per capita consumption is the highest in the world in countries such as Burundi, Rwanda, and Uganda. The yield varies significantly, on average the yield in Burundi, Rwanda, and Uganda are 918 kg/ha, 671 kg/ha, and 638 kg/ha, respectively. Identifying and minimizing yield limiting factors is an ongoing concern for many bean improvement programs (Gepts *et al.*, 2008) in the region. In this review we describe and discuss some aspects about the bean rust research. In addition, we present common bean breeding initiatives in Africa and the recent development of common bean breeding strategy in Uganda.

Rust pathotypes. Pathogenic diseases are one of the main causes of yield and quality losses in the common bean crop worldwide (Thiago *et al*., 2013). This is because the majority of bean production is dependent mainly on the use of inferior landrace varieties which are generally low yielding due to susceptibility to the major disease stresses (Legume Innovation Lab for Collaborative Research on Grain Legumes FY 2013 – 2014 work-plan). The economic losses caused by diseases results from reduction of seed quality and yield. One of the most widespread and important diseases of common bean is rust, caused by a highly variable basidiomycete fungus *Uromyces appendiculatus* (Pers.Pers.) Unger which has a narrow host range- attacks only common bean (Thiago *et al*., 2013) and soybean rust caused by the fungus *Phakopsora pachyrhizi*, which has a broad host range-attacking other leguminous crops. *U. appendiculatus* is known to have high virulence diversity and occurs in many different regions of the world (Jochua *et al.*, 2008). Yield loss attributed to bean rust ranges from 18% to 100%and damage is particularly high in humid and tropical areas, where severe epidemics are frequent (Omunyin *et al*., 1984; Stavely and Pastor-Corrales, 1989; Kimani *et al*., 1990).

Virulence diversity of *U. appendiculatus* was first reported by Harter *et al*., in 1935. The first 20 physiologic races of *U. appendiculatus* were identified in the United States in 1941. Sandlin *et al*. (1999) reported that several other virulence phenotypes have been identified from 1952 to 1996 with over 300 races reported from different parts of the world. These races have been used in breeding programs for identifying and enhancing rust resistance in bean germplasm, although several of these races still cause major losses in Latin America and Africa. It has been reported that rust pathotypes have shown to have an

evolutionary relationship with their hosts, resulting from continuous adaptation to changes in host morphology, biochemistry, and ecology. This allows individual components in the pathosystem to coexist in a dynamic equilibrium with each other (Sandlin *et al*., 1999).

To distinguish races of rust pathotypes, a common method used is the virulence reaction after pathogen inoculations of a set of differential bean lines or cultivars composed of different single or multiple rust resistance genes occasionally has been used to describe virulence diversity of populations of *U. appendiculatus* (Sandlin *et al*., 1999). Since 1983, a set of differential host genotypes was used to distinguish races of rust pathogens. A total of 19 standard bean rust differential lines or cultivars has been used to distinguish races and pathotypes of *U. appendiculatus* (Sandlin *et al*., 1999) this set was modified in 2002 to 12 standard bean rust differentials during the Third International Rust Workshop in South Africa (Liebenberg and Pretorius, 2010). Numerous races of the pathogen worldwide have been defined because of these differentials with 26 identified resistance genes. Another method of measuring diversity of rust pathogens is through the use of molecular markers such isozyme and DNA based markers analysis (Sandlin *et al*., 1999).

Breeding for rust resistance. According to Souza *et al*. (2011) thirteen dominant rust resistance (RR) genes (Ur-1 to Ur-13) have been identified. In addition to these genes, other important unnamed genes have been identified, such as those present in the common bean cultivars as BAC6, CNC, CSW 643, Dorado, Ouro Negro and PI 260418. The appropriate characterization of RR genes from different origins whether Mesoamerican or Andean is essential for the future for developing breeding for common bean resistance to *U. appendiculatus*. Interestingly, new sources of resistance are always identified and characterized because of the high virulence diversity and variability present in the pathogen population (Araya *et al*., 2004; Souza *et al*., 2011).

Although some bean cultivars with single genes for resistance to *U. appendiculatus* have been developed, most of them were overcome by the likely appearance of new races of the pathogen. The highly variable nature of the rust pathogen, *Uromyces appendiculatus*, and the rapid breakdown of major gene resistance present in bean cultivars has been a challenge to bean breeders working to develop durable resistance to bean rust. Pyramiding different resistance genes and mechanisms (specific, adult plant, slow rusting, reduced pustule size, and pubescence) should prolong the life of a bean cultivar by creating a more durable resistance complex (Souza *et al*., 2011).

Status of breeding for rust resistance in Africa. In Africa, the first report of the fungus was in 1909 in South Africa in Transvaal province, although it has existed for many years and was noted that over the years the pathogen is widespread and by 1945, all provinces as well as in Zimbabwe and Mozambique in 1945. It occurs widely in Africa in at least 19 of the 20 eastern and southern African countries but regularly reaches epidemic proportions in the cooler, more humid highland areas, on the eastern escarpment, and in the islands of Madagascar and Mauritius (Allen 1995; Liebenberg and Pretorius, 2010).

According to the report by Liebenberg and Pretorius (2010) on rust diversity in southern African countries which include eight (8) South African provinces and neighbouring countries of Swaziland, Lesotho, Zimbabwe, Mozambique, Malawi, and Tanzania. The reaction of the first (1983) common bean international differential set and other germplasm to 248 single pustule isolates collected resulted into 44 race-groups. The isolates were generally avirulent on accessions with the resistance genes Ur-3+, -5 or -11, as well as Compuesto Negro Chimaltenango (CNC) and A 286, all small seeded, and the most useful sources were accessions carrying both Ur-3 and Ur-11. Isolates were generally virulent on large seeded accessions (with, among others Ur-4, -6 or -9), reflecting the preference for large seeded beans in southern Africa and co-evolution of host and pathogen. No large seeded accessions showed broad resistance.

According to Wortmann *et al*. (1998), rust is responsible for an estimated 191,400 t per annum yield loss in sub-Saharan Africa. Bean rust is particularly endemic and severe disease in eastern and southern Africa (Wortmann *et al*., 1998; Kima ni *et al*., 2002). Total yield loss has been experienced on susceptible cultivars in places like Kenya (Liebenberg and Pretorius, 2010; Arunga *et al*., 2012). No single cost-effective or efficient control measure can be recommended to prevent rust infection in all cases or different regions worldwide. Disease management practices for bean rust control include crop rotation, soil incorporation of bean plant debris, planting within recommended dates, growing resistant cultivars, and timely spraying of fungicides. However, the use of plant resistance not only is harmless to the environment but also an economically sound strategy compared to chemical control. The incorporation of multiple resistance genes into locally adapted cultivars remains the most cost effective control measure for rust especially true for small farmers with low technology inputs (Jochua *et al.*, 2004; Liebenberg and Pretorius, 2010).

Perspective. A pre-requisite for most rust resistance breeding programs is knowing the biology, ecology and diversity of rust pathotypes and sources of resistance from major bean growing regions. Such knowledge is needed to successfully develop and deploy resistance against the pathogen. In Uganda, rust has been identified as an emerging common bean disease sequel to the report of the severity of soybean rust in Uganda (Tukamuhabwa *et al*., 2010; Obua *et al*, 2012) and the fact that the country is one of the bean producing countries in Eastern Africa (Kiwuka *et al*., 2012). These has contributed to rust research being given current attention and priority because the potential of the bean as a food security crop for the majority of Ugandans is undermined gravely by the threat rust disease pose (Wortmann *et al*., 1998) . Thus, there is need to address this problem through breeding of new resistant common beans varieties.

At the moment, NARO, CIAT, Makerere University and other research organizations in the great lakes region are currently undertaking research to this effect. In this respect, a study geared towards identifying the pathogenic variability of rust disease, and sources of resistance to rust pathogen of common bean in Uganda is underway. In addition, the study will determine the mode of inheritance of rust resistance in some Ugandan market class cultivars, and quantifying of yield loss of some Ugandan market-class dry bean varieties resulting from infection by Ugandan rust biotypes.

Acknowledgement

Authors thank the Carnegie Corporation of New York, USA for financing this study. Gratitude is also extended to the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM); National Crops Resources Research Institute (NaCRRI), Namulonge, Uganda; Makerere University, Centro Internacional de Agricultura Tropical (CIAT), Kawanda, Uganda and University of Port Harcourt, Nigeria for various forms of support.

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