Research Application Summary

Inheritance of phosphorus use efficiency and resistance to anthracnose in selected sorghum genotypes grown in the acid soils of western Kenya

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Abstract

The acid soils of Western Kenya where most of the sorghum is grown have very low available phosphorus, and thus cannot support optimal sorghum productivity. In addition, foliar anthracnose (*Colletotrichum sublineolum* L.) also reduces sorghum yield. Inorganic phosphorus fertiliser supplementation is not economically viable for resource constrained farmers in these areas. Since both problems tend to occur together, there is need for varieties that carry both anthracnose resistance and high phosphorus use efficiency (PUE). This study seeks to determine the mode of inheritance to PUE and resistance to anthracnose to support breeding for multiple stress tolerance in sorghum. Crosses were made between parents contrasting for the two traits and genetic analysis conducted on F_2 progeny for both traits. Recombinant F_2 populations were screened at Sega, a low P site in Western Kenya for PUE and at Kibos, a disease hotspot for anthracnose reaction. It is expected that some families/recombinants will be recovered that are PUE and resistant to anthracnose. Such lines will be advanced to develop varieties with multiple stress tolerance to both stresses. Such varieties will have potential for cultivation in western Kenya and Uganda.

Key words: *Colletotrichum sublineolum*, Kenya, phosphorus use efficiency, Uganda

Résumé

Les sols acides de l’ouest du Kenya, où la plupart du sorgho est cultivé, ont un très faible taux de phosphore disponible, et ne peuvent donc pas soutenir la productivité optimale du sorgho. En outre, l’anthracnose foliaire *(Colletotrichum sublineolum* L.*)* réduit également le rendement du sorgho. La supplémentation en engrais phosphatés inorganiques n’est pas économiquement viable pour les agriculteurs pauvres en ressources dans ces régions. Depuis que ces deux problèmes ont tendance à se produire ensemble, le besoin s’avère pour les variétés qui portent à la fois la résistance à l’anthracnose et la haute efficacité d’utilisation du phosphore (PUE). Cette étude vise à déterminer le mode de transmission de PUE et de la résistance à l'anthracnose pour soutenir la reproduction pour la tolérance aux stress multiples dans le sorgho. Des croisements ont été réalisés entre les parents contrastés pour les deux traits et les analyses génétiques menées sur la descendance de F2 pour les deux traits. Les populations recombinantes de F2 ont été dépistées à Sega, un site à faible taux de P à l'ouest du Kenya pour l'efficacité d'utilisation du phosphore PUE et à Kibos, un point chaud de la maladie pour une réaction à l'anthracnose. Il est prévu que certaines familles / recombinants seront récupérés ceux qui sont efficaces d'utilisation de P et résistants à l'anthracnose. Ces lignes seront avancées à développer des variétés avec la tolérance aux stress multiples pour les deux stress. Ces variétés seront possibles d'être cultivées à l'ouest du Kenya et de l'Ouganda.

Mots clés: *Colletotrichum sublineolum*, Kenya, efficacité d'utilisation du phosphore, Ouganda

Background

Sorghum (*Sorghum bicolor* (L.) Moench) is an important staple cereal for many communities. It is the fifth most important cereal crop in the world after wheat, maize, rice, and barley, and the second most important cereal crop (after maize) in Sub-Saharan Africa (Zidenga, 2004). In Kenya, it is grown principally in the often drought-prone, marginal areas of Eastern, Nyanza, Western and Coastal provinces (EPZA, 2005). Western Kenya produces over 70 % of sorghum in the country. Despite the crop's importance, sorghum yields are still very low in Kenya; 1.0t/ha compared to 3.0t/ha obtained in developed countries. This is attributed to a number of factors including planting of low yielding sorghum varieties, biotic constraints such as weeds, pests and diseases such as anthracnose, and abiotic constraints for example unreliable rainfall and soil factors including poor mineral nutrition and low availability of P to plants. Sorghum production in western Kenya is done on soils that are generally low in P at 2 to 5mg/kg soil compared to optimal levels of 10 to 15mg/kg soil (Okalebo *et al*., 2004; Obura *et al*., 2008). Low soil P availability is therefore among the primary factors limiting sorghum production in Kenya and in acid soils in general. Application of inorganic P soil amendments is the conventional way of addressing this problem. However, resource poor farmers who cannot afford inorganic P fertilisers dominate sorghum farming in Kenya. In addition, the utilisation efficiency of P by plants especially in the acid soils is often low, ranging from 10 to 30% in the year of application (Zhul *et al*., 2001).

This inefficiency is conditioned by P fixation by clay minerals making phosphorus not readily available for absorption by plants even though soils may contain much more phosphorus than necessary for optimum plant growth (Kaeppler *et al*., 2000; Obura *et al*., 2008).

Another challenge to sorghum production is the foliar disease anthracnose (*Colletotrichum sublineolum*). The pathogen infects all the above ground tissues of the plant; however, the foliar infection is most widely distributed. Anthracnose may reduce grain yield by up to 50% in susceptible cultivars and in severe cases, it may kill plants before heading or maturity (Harris and Cunfer, 1976). Although anthracnose tolerant varieties are available, this only applies to some sorghum agro-ecologies. Further, although chemicals may be used for disease control, they are not cost effective.

For cereals in general, the use of host plant resistance and/or enhanced abilities is the only practical means of controlling sorghum diseases in the low input agricultural systems. This is also due to the low return to investments per unit area of inorganic materials used. It is therefore important to ensure that genetic resistance to endemic pathogens is incorporated into improved cultivars before they are released. Although anthracnose tolerant or P efficient sorghum cultivars exist, they are tolerant to single stresses and may thus not provide good solutions for multiple stresses common in agro-ecologies. This study therefore aims at identifying sorghum genotypes with both high phosphorus use efficiency and resistance to anthracnose.

Literature Summary

Sorghum is one of the most important cereal crops and a major staple food crop supporting the lives of millions of people across the globe and particularly in the developing world **(**FAO, 2009). In Kenya, sorghum is considered an important food crop where it is consumed in some parts of the country as a staple food. Besides being used as a food crop, sorghum is used as an animal feed and, to a lesser extent, as a raw material in commercial food industries. It is a major source of income to small scale farmers who are its major growers (Enserink, 1995). Due to its drought tolerance properties, sorghum is important in marginal rainfall areas of the world. Its ability to perform well under limited moisture and high (or low) temperature conditions where other crops often fail, makes it an extremely important crop in providing the necessary food for millions of people in both developing and developed countries.

Another challenge to sorghum production is the foliar disease anthracnose (*Colletotrichum sublineolum*). The pathogen infects all the above ground tissues of the plant; however, the foliar infection is most widely distributed. Foliar infection can occur at any stage of plant development, but symptoms are usually in general observed about forty days after seedling emergence. Anthracnose may reduce grain yield by up to 50% in susceptible cultivars and in severe cases, it may kill plants before heading or maturity (Harris and Cunfer, 1976). Although anthracnose tolerant varieties are available, this only applies to some sorghum agro ecologies. Chemicals though used for disease control, are not very effective because the disease causal agent, *Colletotrichum sublineolum* has been reported to be highly variable accounting for rapid resistance breakdown (Souza-Paccola *et al.*, 2003). For cereals in general, the use of host plant resistance and/or enhanced abilities is the only practical means of controlling sorghum diseases in the low input agricultural systems, characteristic of the developing world. This is also due to the low return to investments per unit area of inorganic materials used. It is therefore important to ensure that resistance genes to endemic pathogens are incorporated into improved cultivars before they are released.

Most sources of anthracnose resistance possess multiple genes (Thakur and Mathur, 2000). However, little is known about the genetics of plant resistance with only a few sources being used in sorghum improvement programmes. Resistance to anthracnose is considered to be inherited as a multigenic trait and significantly influenced by the environmental conditions. This type of resistance can be expressed as a reduced infection frequency, a slower rate of development in the host, and a slower rate of spore production over a shorter period of time (Casela *et al.*, 1993).

In a field evaluation on soils of low P, Schaffert *et al.* (2001) identified sorghums that were either efficient or inefficient in P acquisition and others that were responsive or non-responsive to applied P based on their grain yield. Although anthracnose tolerant or P efficient sorghum cultivars could be found, these are tolerant to single stresses thus may not provide good solution because in farmers' fields, a combination of more than one of these factors is present, and hence the need for multiple stress tolerant lines.

Study Description

Two sites namely Kibos and Sega, both located in Western Kenya are being used for this study. Kibos, 0^o 3'S, 34^o 51'Ea, an anthracnose hotspot, has an average elevation of 1169m above the sea level with an average annual rainfall of between 1000-1400mm. The soils are mainly clay. Sega, 0Ú15'N, 34Ú15'E, the second site with an altitude of 1300 m has a mean annual rainfall of 1600 – 1800 mm, is located in Siaya district of Nyanza province, western Kenya and is known to be low in available P. At this site, the field evaluations of sorghum families for P efficiency will be carried out; Sega soils are acidic (pH- 5.1) with low P (2-5 mg/kg, Kisinyo *et al*., 2009). Six stable inbred lines (G2, K5e, L6, P5, C1& O2) contrasting for the two traits are the parents being used in this study. A six-parent half diallel cross has been used to generate F_1 progeny using the hot emasculation technique (House 1985). The F_1 seed obtained have been advanced to F_2. Genetic analyses are being performed on the F_2 segregating progeny for the mode of gene action and their role in the inheritance of resistance and PUE respectively. F_2 progeny are being screened at Sega, a low P site in Western Kenya for PUE and at Kibos, a disease hotspot for anthracnose reaction. It is expected that some families/recombinants will be recovered which will be PUE and also resistant to anthracnose. Such lines will be developed further in a separate study into varieties that show multiple stress tolerance to both stresses. Such varieties could be availed to farmers to improve sorghum yield in the anthracnose endemic and low P soils of western Kenya and Uganda.

Research Application

From the parental crosses made, 13 successful crosses (Table 1) have been obtained and these are currently being advanced to F_2.

Genetic analysis will be done in the F_2 segregating population for the mode of gene action and their role in inheritance to the two traits. While in the field, the parents G2, C1 and O2 have

Table 1. Successful crosses made between sorghum parental lines contrasting for PUE and anthracnose resistance.

Parents	Source	Successful crosses
G2	MOI	G2 x (P5,L6,P5,O2,P5)
K5e	MOI	K5e x (L6,L6)
L6	MOI	L6 x C1
P5	MOI	P5 x (C1,C1)
C1	ICRISAT	C1 x P13
O2 (Seredo)	TANZANIA	O2 x (G2,K5e)

been observed to be completely resistant to anthracnose, L6 is susceptible to stem anthracnose but completely resistant to foliar anthracnose, whilst K5e is susceptible to stem anthracnose and P5 is highly susceptible to both stem and foliar anthracnose. The segregation patterns of PUE and anthracnose resistance are still being evaluated. The observations so far suggest that multiple genes for anthracnose resistance occur and that tissue specific infection may be controlled by different genes.

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