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Early storage root bulking index and agronomic traits associated with early bulking in cassava

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ABSTRACT

One of the attempts by farmers in counteracting the devastating effects of cassava brown streak disease (CBSD) on yield and quality of cassava is early harvesting. However, most varieties grown by farmers are often late bulking which increases the disease severity while on the other hand early harvesting results in significant yield losses. Farmers, therefore, need early storage root bulking cassava varieties in order to reduce the time to harvest leading to a faster rate of return to investment, while at the same time avoiding devastating effects of CBSD on yield and quality of cassava. The study was, therefore, conducted to identify high-yielding and early storage root bulking cassava genotypes as well as traits associated with early storage root bulking and estimate yield loss if any due to early harvesting. The overall aim was to generate information that would guide future improvement programmes for high-yielding and early-bulking cassava varieties in Malawi and other countries facing similar challenges. Trials were implemented using a square lattice design with three replications at two locations for two growing seasons with three harvest intervals (6, 9 and 12 months after planting, MAP). High yields were obtained of up to 9.5 t/ha at 6 and 17.8 t/ha at 9 MAP. Furthermore, the study revealed that yields obtained at 9 MAP were higher than those obtained at 12 MAP for some genotypes which suggests that such genotypes would be considered as early storage root bulking. Simple correlation analysis identified harvest index, storage root number, storage root diameter and storage root length as the selection criteria to achieve high fresh storage root yield (t/ha) and dry mass yield (t/ha). Path coefficient analysis allocated harvest index and shoot mass as the major selection criteria in improving fresh storage yield and dry mass yield. The study suggests that both source and sink capacities were important for determining early yield. Therefore, these two traits are the key determinants of early storage root bulking and should be used when selecting early-bulking cultivars and indirectly selecting for storage root number, storage root diameter and storage root length.

1. Introduction

Cassava (*Manihot esculenta* Crantz) plays an important role in traditional tropical cropping systems, more particularly on small farms in the subsistence farming sectors. It is often grown in mixed stands with other food or cash crops. Cassava's importance is mainly derived from its wide range of adaptation, its tolerance to low soil fertility, drought, pests and diseases, a high dry matter yield per hectare, flexibility in planting and harvesting and diverse range of utilization (Ceballos et al., 2004; FAO, 2013; Leihner, 2002; MoAFS, 2007; Onwueme, 1978; Westby, 2002).

Cassava production is affected by numerous constraints that include pests and diseases, in particular cassava mosaic disease (CMD) and cassava brown streak disease (CBSD), low yield potential, long growth period/late storage root bulking, early postharvest deterioration, use of low-yielding varieties, and shortage of labour, land and capital for cassava production (Dahniya, 1994; IITA, 1990). The combination of late storage root bulking and CBSD infections makes the farmer vulnerable to food insecurity, as by the end of the season she/he realises yields that are well below the potential of the crop.

Cassava has no defined maturity period, which means that it can be harvested whenever economic yields can be obtained. Maximum

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dry matter (DM) accumulation in storage roots generally occurs between 300 and 360 days after planting (DAP), and is mainly influenced by changes in temperature (Alves, 2002). This is the period when most of the cassava is harvested (that is, 12 months after planting, MAP). However, the highest rates of DM accumulation in storage roots occur within 180–300 DAP (6–10 MAP), and varies according to genotype and environment. This infers that cassava harvesting can start as early as 6 MAP. According to FAO (2013), in cases where the storage root is used as food, the best time to harvest is between 8–10 MAP. Studies have reported high dry matter storage root yield (9.0–14.5 t/ha) at 7 MAP (Mtunda, 2009; Okogbenin and Fregene, 2002) and high fresh storage root yields (15.5–28.0 t/ha) at 6 and 7 MAP (Asante, 2010; Mtunda, 2009; Nair and Unnikrishnan, 2006; Okechukwu and Dixon, 2009; Tumuhimbise, 2013). A good measure of DM distribution in storage roots is its harvest index (HI, the ratio of storage root mass to the total plant mass), which represents the efficiency of storage roots production. Significant differences in HI have been reported among cultivars, indicating that it can be used as a selection criterion for higher yield potential in cassava (Alves, 2002; Kawano, 2003). HI values of 0.49–0.77 have been reported after 10–12 MAP (Alves, 2002), which means that varieties exhibiting HI within this range at 6–9 MAP could be early storage root bulking. Since early-bulking is partly due to a genotype's ability to quickly accumulate assimilate reserves in its storage roots (Alves, 2002; Segnou, 2000), there is a need to exploit this variability in order to breed for early storage root bulking cassava varieties.

Development of early storage root bulking varieties has received much attention across the globe (Kamau et al., 2011; Nair and Unnikrishnan, 2006; Okechukwu and Dixon, 2009; Okogbenin and Fregene, 2002; Okogbenin et al., 2008; Olasanmi et al., 2014; Suja et al., 2010; Tumuhimbise, 2013; Tumuhimbise et al., 2014; Wholey and Cock, 1974), and more particularly in the wake of the CBSD epidemic which is threatening the cassava industry in east and southern Africa. Late harvesting of cassava (mainly due to late bulking) contributes to high CBSD incidence, which increases with plant age (Alvarez et al., 2012; Gondwe et al., 2003; Hillocks et al., 2001; Hillocks et al., 2002; Rwegasira and Rey, 2012). It is clearly documented that most farmers prefer early-bulking varieties that can also withstand pests and disease damage (Agwu and Anyaeche, 2007; Benesi et al., 2010; Chipeta et al., 2016; Dahniya, 1994; Munga, 2008; Okechukwu and Dixon, 2009; Tumuhimbise et al., 2012). A greater commitment, therefore, has to be made to develop early-bulking cultivars so that they reach full bulking before the disease (root necrosis) becomes severe. This in turn would effectively reduce the production period resulting in a faster rate of return to investment. In Malawi, due to scarcity of livestock feed during later months of the year (dry periods), most livestock fend for themselves which means keeping cassava in the field for longer time exposes the crop to the animals. This in turn increases cost of production as farmers resort into guarding their fields and if not, crop loss due to animal feeding. Therefore, productive early storage root bulking varieties would not only provide good storage root quality and productivity per unit area of land, but with early harvesting would also facilitate the release of land for other farming activities (for example, early land preparations for the following season, production of other short duration crops such as vegetables more especially in wetlands or areas close to water sources), and reduce exposure to biotic and abiotic stresses thereby increasing productivity. The objectives of this study were to: (1) identify high-yielding and early storage root bulking cassava genotype, (2) determine agronomic traits influencing early storage root bulking through path coefficient analysis, (3) estimate yield loss if any due to early harvesting.

2. Materials and methods

2.1. Plant material

Planting material was sourced from national agricultural research stations and farmers' fields. A total of 16 genotypes were evaluated (Table 1) and their selection was based on their popularity with farmers and their response to various diseases prevalent in Malawi.

2.2. Experimental sites

The trials were conducted in Malawi at two sites, Chitala Agricultural Research Station in Salima district (central Malawi) and Kasinthula Agricultural Research Station in Chikwawa district (southern Malawi) over two growing seasons (2014 and 2015). Chitala Agricultural Research Station lies on latitude 13°40′ South and on longitude 34°15′ East. It is at an altitude of 606 m above sea level. The station receives rains within three months normally between December and March and has mean annual temperatures of 28 °C maximum and 16 °C minimum. The soils are sandy clay to sandy clay loam with the pH range of 4.4–6.7. Kasinthula Agricultural Research Station is located at 16°0′S latitude, 34°5′E longitude and 70 m above sea level. The yearly average maximum and minimum temperatures of the site are 35.6 °C and 18.6 °C, respectively, and annual rainfall is 520 mm on average. Table 2 details soil characteristics of the two sites.

2.3. Experimental design

The trials were laid out using a square lattice design constituting 16 genotypes. Three replications per site were used and each replication had four blocks and each block had four main plots (4 × 4). A genotype within the plot was considered as the main plot while harvest time as subplot. A gross plot consisted of five ridges and the inner three ridges as net plot excluding the most outer plants as borders (each ridge consisted of six plants which gave 12 net plants and 30 gross plants). Plants were spaced at 1.0 m × 1.0 m and 2.0 m between replications. The trials were planted in January in 2014 and repeated in 2015 under rain fed conditions and neither fertilizers nor pesticides were applied. Manual weeding was done when necessary.

2.4. Data collection

Data for individual genotypes were collected at harvest 6, 9 and 12 MAP for the following traits: fresh storage root yield (t/ha), dry mass yield (t/ha), shoot mass (t/ha), number of storage roots per plant, storage root length (cm), plant height (cm), plant height at first branching (cm), harvest index, storage root dry mass content (%), starch content (%), storage root diameter (cm) and levels of branching. At each harvest interval, the unit of measurement was three plants per plot per harvest time.

Percentage dry mass (DM), starch content and harvest index (HI) were determined as described by Fukuda et al. (2010):

1. Dry mass (DM) % = 158.3 × SG − 142.
2. Starch content (%) = 112.1 × SG − 106.4; Where SG = specific gravity = Wa/(Wa-Ww) Where Wa = mass in air of storage roots (kg) and Ww = mass in water of storage roots (kg).
3. Storage root dry matter yield $(\text{t/ha}) = \frac{\text{Fresh storage root yield} \times \text{DM\%}}{100}$
4. Harvest index (HI) $= \frac{\text{Mass storage roots}}{\text{Mass storage roots} + \text{above ground mass}}$