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Weed management in maize using crop competition: A review

Blessing Mhlanga [a, *], Bhagirath Singh Chauhan [b], Christian Thierfelder [c]

[a] University of Zimbabwe, Department of Crop Science, P. O. Box MP 167, Mount Pleasant, Harare, Zimbabwe
[b] The University of Queensland, Queensland Alliance for Agriculture and Food Innovation, Leslie Research Facility, Toowoomba, Queensland 4350, Australia
[c] International Maize & Wheat Improvement Centre, Zimbabwe, P. O. Box MP 163, Mount Pleasant, Harare, Zimbabwe

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ABSTRACT

Weeds are a major constraint to crop production, and are responsible for considerable yield losses in maize production systems throughout the world. Herbicides are widely used for weed control in maize production systems, but can have negative environmental consequences. Researchers have evaluated the use of crop competition and suppression to manage weeds in various crop combinations, including maize-based systems. Crop competition in maize may involve techniques such as reduced row spacing, increased planting density, and the use of competitive cultivars that exhibit weed suppressive potential. In this review, examination of the literature has revealed the considerable value of using crop competition in integrated weed management programs. Research has demonstrated that narrowing row spacing to half the standard distance reduced weed biomass by 39–68%, depending on weed species. Researchers have also demonstrated that increasing maize planting density by up to twice the standard rate achieved a reduction in weed biomass of 26–99%. While little research has been conducted into the use of competitive maize cultivars for weed management, several studies have documented cultivars with potential to suppress weeds. Attributes of weed competitive cultivars include high leaf area index, and other elements of leaf architecture that improve light interception by the crop, so increasing the shading of weeds. Combining crop competition methods with other agronomic practices can increase their effectiveness in controlling weeds. For example, biomass of *Setaria italica* (L.) Beauv was reduced by 60% when maize planting density was increased by 1.5 times the recommended spacing, and this effect was more pronounced when fertilizer was banded rather than broadcast. In summary, the strategic use of crop competition to control weeds has been a success in many regions, and is an important tool in integrated weed management. The importance of crop competition methods has particular relevance where farmers are unable to afford herbicides, as making use of crop competition is more economical.

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* Corresponding author.
E-mail address: blessing.mhlangah@gmail.com (B. Mhlanga).

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1. Introduction

Maize is one of the world's major cereal crops, ranking third in importance after wheat and rice (Lashkari et al., 2011). In Southern and Eastern Africa, it is the main source of food and agricultural income for smallholder farmers. However, the amount of maize produced in the continent of Africa is below the world average (Fig. 1), and this is mainly the result of huge yield gaps due to poor weed management practices, coupled with low resource inputs (FAO, 2014; Lobell et al., 2009). Weeds regularly cause devastating maize crop losses (Bajwa et al., 2015). For example, they account on average for 50–90% of crop loss in Africa (Chikoye et al., 2005). For example, the invasion of maize fields in Africa by *Striga asiatica* (L.) Kuntze has been reported to cause total crop failure in some cases (Khan et al., 2008). Weed management in Africa suffers from low use of herbicides and mineral fertilizers, in addition to lack of available labour for weeding, often resulting in delays that defer weeding past the stage where it is possible to prevent economic damage (Nyamangara et al., 2014; Nyanga et al., 2012). In Africa, weed control is mainly carried out by hand hoeing, but this is only feasible on small areas due to emerging labour constraints in rural districts (Nyamangara et al., 2014). Moreover, declining soil fertility has led to the prevalence of devastating weeds such as *Striga*, *Cynodon dactylon* L., *Richardia scabra* L., which are difficult to control and cause severe crop losses (Reda et al., 2005).

In more developed parts of the world, such as Australia, which are characterised by higher agricultural inputs, farmers rely heavily on the use of herbicides to control weeds (CropLife/Grains Research and Development Corporation, 2008). Herbicides are an efficient tool in the control of weeds, and their proper use can reduce yield losses caused by weeds by up to 13% (Oerke and Steiner, 1996). In the USA, the use of genetically modified glyphosate resistant maize (Round-up® ready maize) accounts for about 10% of the total land under maize production (Gianessi, 2005). Glyphosate resistant maize allows for the use of glyphosate in controlling weeds throughout the season. Glyphosate-resistant maize has been shown to be economical compared to conventional cultivars, but their adoption in Europe and certain other parts of the world is low due to opposition to genetic modification, the availability of wide spectrum of crop alternatives, as well as environmental concerns associated with herbicide use (Gianessi, 2005).

Herbicides in variable herbicide groups, ranging from pre- to post-emergent, can be used in the efficient management of weeds, thus ensuring an all-season-round weed-free environment for crop production (Mathers and Parker, 2013). Some researchers have recommended the use of herbicides as being economical compared to mechanical weed control (Gianessi, 2014; Muoni et al., 2013). However, the over reliance on herbicides in developed regions has led to increased levels of resistance in certain weed species (Culpepper et al., 2004; Hall et al., 2014; Hull et al., 2014), making the use of herbicides more and more questionable now and in the future. In New Zealand, a spectrum of weeds in maize have been reported to be resistant to the commonly used herbicide atrazine, including *Chenopodium album* L. and *Solanum nigrum* L. (Mathers and Parker, 2013). These cases of resistance have led to calls for increased dosages that would contribute to increasing environmental pollution (Koch, 2010; Reganold et al., 2001). This is particularly relevant for the use of atrazine, which remains in the soil for many years (Helling et al., 1988).

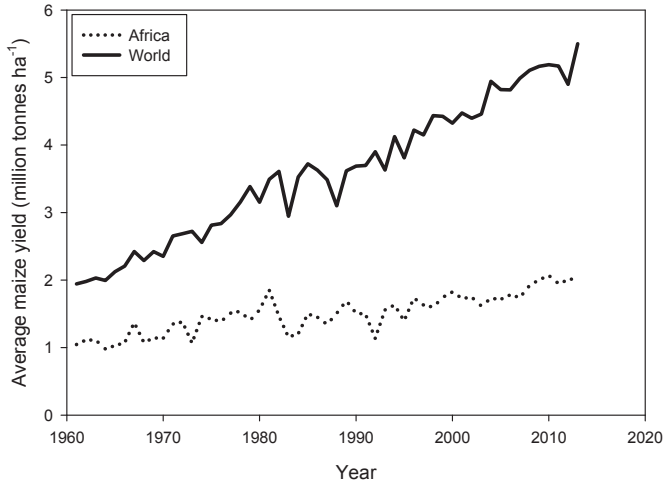

Fig. 1. Average maize yield production in Africa and the world as from 1960 to 2013. Data source: FAO (2014).

Among the other possible means of minimizing resistance to herbicides by weeds is the avoidance of repeated use of herbicides from the same mode-of-action group (Mathers and Parker, 2013). However, this requires correct identification of the weeds, and a proper decision on which chemical to use, to achieve successful control of the weeds (Mathers and Parker, 2013). In developing countries where the choice of herbicides is limited, rotation to other herbicides is restricted. Despite the efforts made by chemical companies to reduce weed resistance, weed evolution towards resistance to chemicals is not at a standstill (Jasieniuk et al., 1996; Vencill et al., 2012; Délye et al., 2013; Matzrafi et al., 2014). Thus, weed management through herbicides is becoming more and more of a challenge due to weed resistance.

It is widely accepted that sustainability is key to increasing agricultural productivity over the long term, while conserving the environment. Crop production in the developing world is changing. For example, minimum tillage and residue retention are advocated by many researchers (Thierfelder and Wall, 2009; Guto et al., 2012a, 2012b; Sissoko et al., 2013). These changes have in turn resulted in shifting weed flora, requiring new strategies to control the emerging spectrum of weeds (Chauhan et al., 2012; Mhlanga et al., 2015). Some researchers have shown that the use of cover crops, and retaining their residues in cropping systems, is very efficient in controlling weeds. However, this can lead to a shift in weed flora, and the value for weed control is dependent on the performance of each specific cover crop (e.g. Mhlanga et al., 2015). Research has also highlighted some of the other challenges encountered with the use of cover crops, such as the preferences of the farmer and the availability of seed. In sub-Saharan Africa (e.g. in Malawi) where the land holding size is small, integration of cover crops may be difficult, as these would replace the main crops without giving a marketable return in the same year, thus limiting adoption of this practice (Mhlanga and Thierfelder, 2015).

Undoubtedly, with these yield losses caused by weeds, challenges faced in weed control, and the need to feed the ever-growing human population, there is need for a shift to more reliable and economic methods of weed control. Some researchers have advocated for ecologically-based weed management tools, as these have the potential to meet the challenges associated with conventional weed management (Chauhan et al., 2012; Chauhan, 2013). In smallholder ecological farming systems, where the use of herbicides is restricted, weeds are viewed as a source of diversification and groundcover. In such farming systems, weed control is effectively achieved through slashing with a sickle at a critical stage. This not only helps to maintain a healthy soil environment, but also increases the needed groundcover to reduce temperature extremes, protect the soil against splash erosion and conserve moisture.

The use of crop competition is a potentially valuable cultural