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Effect of herbicide application on weed flora under conservation agriculture in Zimbabwe

Tarirai Muoni [a,*], Leonard Rusinamhodzi [b], Joyful T. Rugare [a], Stanford Mabasa [a], Eunice Mangosho [c], Walter Mupangwa [b], Christian Thierfelder [b]

[a] University of Zimbabwe, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe
[b] CIMMYT, P.O. Box MP 163, Mount Pleasant, Harare, Zimbabwe
[c] Ministry of Agriculture, Weed Research Team, Henderson Research Institute, Private Bag 2004, Mazowe, Zimbabwe

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A B S T R A C T

Increased challenges of weed control in the smallholder farming sector of southern Africa have often resulted in small yields. The objective of this study was to evaluate the effects of different weed control strategies on weed flora and composition under conservation agriculture (CA) systems in Zimbabwe. This study was conducted at three on-station trial sites namely Domboshawa Training Centre (DTC), University of Zimbabwe farm (UZ farm) and Henderson Research Station (HRS) in a maize–soybean rotation for four seasons from 2009–2010 to 2012–2013 seasons. Hand weeding was done whenever weeds were 10 cm tall or 10 cm in circumference for weeds with a stoloniferous growth habit. Weed identification was done up to the weed species level, and the Shannon–Weiner diversity and evenness index was used to determine the response of weed flora to herbicides. Results showed that there were more weeds in the early years which decreased gradually until the final season. Weed species diversity was not affected by herbicide application and the results indicated that weed species diversity was small in CA systems. Annual weed species constituted a greater proportion of species, and species richness decreased with the duration of the study. *Richardia scabra* L. and *Galinsoga parviflora* Cav. were the most common dominant weed species at all sites and in all seasons. Moreover, herbicide application had no effect on the evenness of weeds in the plots but site characteristics had a significant effect on the distribution of weed species (weed species evenness). The results presented in this study suggest that herbicide application facilitates a depletion of weed seed bank/number of weeds over time. Thus, herbicide application in CA has potential to reduce weed density, species richness and species diversity in the long term which may lead to more labour savings and larger yields.

1. Introduction

Weed management challenges in the smallholder farming sector have been reported as one of the major causes of low grain yields in southern Africa. Maize grain yield from smallholder farms averages less than 1 t ha^{-1} and this is often not sufficient to support an average farming family (USAID/Zim-AIED, 2013). Weeds are more efficient in competing with crops for nutrients, water and space, and harbour pest and diseases that all have negative effects on yields obtained at the end of the season (Shrestha et al., 2002). Weed management by smallholder farmers has been practised using the mouldboard plough, for families with access to draft power, and through hand hoes by resource poor farmers (Muoni et al., 2013). Most of the smallholders in Zimbabwe use conventional tillage practices for field preparations and for weed control (Vogel, 1994). Although manual weeding using hand hoes is a common practice within smallholder farming, it is labour intensive and is often delayed leading to reduced crop yields (Mashingaidze et al., 2012). Conventional tillage practices often increase soil erosion rates leading to reduced soil quality such as poor soil porosity, nutrient loss and low organic matter content (e.g. Thierfelder and Wall, 2012). Poor soil nutrient statuses in combination with poor weed management practices often contribute to decreased yields. To alleviate this challenge, researchers have suggested a more sustainable method of farming, commonly referred to as Conservation Agriculture.

Conservation Agriculture (CA) is defined as a farming system based on three interlinked principles which are (a) maintenance of

* Corresponding author. Tel.: +263 774311136.
E-mail address: tarirai.muoni@gmail.com (T. Muoni).

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a permanent soil cover through crop residues, (b) diverse crop rotations and (c) minimum soil disturbance (FAO, 2010). Conservation agriculture has potential to make more efficient use of natural resources through integrated management of soil, water and biological resources combined with use of external inputs (FAO, 2010). The use of crop residues helps retaining soil moisture which reduces the negative effects of mid-season dry spells common in southern Africa (Thierfelder and Wall, 2010). Residues can suppress weeds during the growing season if applied in sufficient quantity. Minimum soil disturbance and retention of crop residues reduce the rate of soil loss and increase soil biological activities (e.g. Dube et al., 2012). However, the complexity of weed control in CA systems increases due to an increase in perennial weed species (Gan et al., 2008). This has resulted in a general recommendation for increased use of herbicides in the early years of CA adoption (Wall, 2007).

Herbicides have been reported to be effective and economically feasible in the smallholder farming sector where CA is being practised (Muoni et al., 2013). Herbicides have the ability to reduce substantially the weeding pressure but there are potential toxic side effects for humans and the environment (Kolpin et al., 1998). Among the recommended herbicides are glyphosate [N-(phosphonomethyl) glycine], atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] and metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-2-methoxyl-1-methylethyl) that have different modes of action. Glyphosate is a non-selective systemic herbicide capable to control weeds that have underground rhizomes. Atrazine and metolachlor are selective herbicides that are applied before emergence of weeds and atrazine can also be applied after emergence of weeds and are both effective on broadleaved weeds and some grasses (Croplife, 2006). Rugare and Mabasa (2013) reported that the use of herbicides in CA reduced the variable cost of weed control by at least 21.8% and increased the marginal rate of returns by 306% compared to hand hoe weeding. Although many advantages of using herbicides have been documented, there is little information available on the longer term response of weed species to herbicide weed control strategies in CA systems under Zimbabwean conditions. Increasing the intensity of hand hoe weeding reduces the total weed density and the number of weed species that are observed in the plots (Mashingaidze et al., 2012). Crop rotations also facilitate weed suppression and there may be a different weed species response due to different rotational crops. Several tools can be used to investigate weed species diversity and evenness in a community such as the Shannon–Weiner index (H index for species diversity and E index for species evenness) (Grice et al., 2009). The Shannon–Weiner indices combine species richness (i.e. the number of weed species per area) and species equitability (i.e. how even is the number of species) (Nolan and Callahan, 2006). The hypothesis of this study was that herbicide application in combination with no-till, mulching and crop rotation will decimate the weed species and their density over time. Thus the objective of this study was to evaluate the effects of herbicide strategies on weed flora under conservation agriculture (CA) systems in Zimbabwe.

2. Materials and methods

2.1. Site description

The experiments were established at three research locations namely Domboshawa Training Centre (DTC), Henderson Research Station (HRS) and University of Zimbabwe farm (UZ farm). All the three sites are located in natural region II of Zimbabwe and rainfall pattern is unimodal averaging 700–1000 mm per growing season. Rainfall starts in November and ends in April, and mid-summer temperature ranges from 15.5 °C to 25.0 °C. Domboshawa Training Centre (17°37′S, 31°10′E and 1560 m above sea level (m.a.s.l)) is located on highly variable soils that are classified as moderately deep *Luvisols* and *Arenosols*, and these soils have approximately 5% clay content. Henderson Research Station (17°34′S, 30°54′E and 1136 m.a.s.l) soils are classified as *Arenosols* according to FAO classification originating from granite rocks (Nyamapfene, 1991). The soils at HRS have a high sandy content (>83%) and are generally low in soil organic matter content (Thierfelder and Wall, 2012). University of Zimbabwe farm (17°80′S, 31°50′E and 1503 m.a.s.l) is located on clay soils that have high soil organic matter and are classified as *Chromic Luvisols* under FAO classification (Nyamapfene, 1991).

2.2. Experimental design

The experiment commenced in the 2009–2010 cropping season at all sites with maize as the test crop. The experiment was laid in a randomised complete block design (RCBD) with six treatments, replicated three times at all sites. The treatments were;

i. Hand hoe weeding only.
ii. Paraquat at 0.25 L ha^{-1} a.i (active ingredient) at seeding plus hand hoe weeding.
iii. Glyphosate at 1.025 L ha^{-1} a.i at seeding plus hand hoe weeding.
iv. Atrazine at 1.80 kg ha^{-1} a.i at seeding plus hand hoe weeding.
v. Glyphosate (1.025 L ha^{-1} a.i) + atrazine (1.80 kg ha^{-1} a.i) at seeding plus hand hoe weeding.
vi. Glyphosate (1.025 L ha^{-1} a.i) + atrazine (1.80 kg ha^{-1} a.i) + metolachlor (0.96 L ha^{-1} a.i) at seeding plus hand hoe weeding.

The recommended application rates for the different herbicides were used in this study and treatments with more than one herbicide where tank-mixed and applied at the same time. Manual hoe weeding was done whenever weeds were 10 cm tall or 10 cm in length for stoloniferous weeds, in circumference. A maize–soybean rotation was deployed through the trial period. In 2009–2010 and 2011–2012, a uniform maize crop, using the maize variety Pristine 601, was seeded, whereas soybean (variety Safari) was grown in the 2010–2011 and 2012–2013 cropping season after the maize phase. In the maize phase, maize was grown using planting basins at UZ farm and rip lines at HRS and DTC, and maize harvest residues were used as ground cover at approximately 2.5 t ha^{-1} in seasons 1, 2 and 4. In the third season, soybean crop harvest residues were retained and used as ground cover at approximately 1.5 t ha^{-1}. During the maize phase weeding was done up to four times at DTC and HRS in 2009–2010 season only whilst in 2011–2012 season and at UZ farm weeding was done only three times throughout the growing season. In the soybean phase weeding was done twice only. Maize was seeded at 0.9 m × 0.25 m plant spacing to achieve a target plant population of 44,444 plants ha^{-1}. 150 kg ha^{-1} of Compound D (11 kg N: 21 kg P_2O_5: 11 kg K_2O ha^{-1}) was applied as a basal dressing at seeding and 150 kg ha^{-1} of ammonium nitrate (52 kg N ha^{-1}) was split applied as top dressing at four and seven weeks after emergence. In the soybean phase, inoculated soybean (inoculated with *Bradyrhizobia japonicum*) was seeded at 0.45 m × 0.05 m which translated to a target plant population of 444,444 plants ha^{-1} and no herbicide was applied as initial weed control measure in soybean. A basal application of 150 kg Compound D (11 kg N: 21 kg P_2O_5: 11 kg K_2O ha^{-1}) was applied by dribbling 90 g in every 10 m row. No top-dressing was applied to the soybean.