Crop Protection 53 (2013) 23–28

Contents lists available at SciVerse ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Weed control in conservation agriculture systems of Zimbabwe: Identifying economical best strategies

Tarirai Muoni [a,*], Leonard Rusinamhodzi [b], Christian Thierfelder [b]

[a] University of Zimbabwe, Faculty of Agriculture, Crop Science, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe
[b] International Maize and Wheat Improvement Centre (CIMMYT), Southern Africa Regional Office, P.O. Box MP 163, Mount Pleasant, 12.5 Km Peg Mazowe Road, Harare, Zimbabwe

A R T I C L E I N F O

Article history:
Received 26 November 2012
Received in revised form
31 May 2013
Accepted 4 June 2013

Keywords:
Conservation agriculture
Weed management
Herbicide use
Smallholder farmers
Economic benefits

A B S T R A C T

Weed management under conservation agriculture (CA), especially when manually controlled is one of the major setbacks for the widespread adoption of CA in southern Africa. This study was conducted at three on-station and three on-farm sites: CIMMYT-Harare, Domboshawa Training Centre and Henderson Research Station (on-station sites), Hereford farm, Madziva communal area and Shamva communal area (on-farm sites). The evaluation focused on the effect of initial herbicide application and succeeding manual weeding whenever weeds were 10 cm tall or 10 cm in length for grasses with stoloniferous–rhizomatous growth habit. Weeds counts, weeding time and grain yields were collected at all on-station sites. At the on-farm sites, weed counts were done before weeding and a number of farmers were timed during weeding. The results showed that herbicides use reduced the weed density and time taken on weeding at all sites. Combining herbicides e.g. atrazine, glyphosate and metalachlor had the lowest weed density and weeding time at all sites. However, the treatments had no effect on maize grain yields suggesting that appropriate and timely manual weeding reduced crop/weed competition. Herbicides treatments had higher input costs than manual weeding due to the additional cost of herbicide but the treatment with manual weeding only had more overall labour days compared to the mixture of three herbicides. In order to achieve economic benefits, smallholder farmers may use the time for value addition e.g. expand cropped land area, use time for value addition, or sell new products on the market. Herbicides use reduces the manual labour needed to control weeds and minimise total crop failure due to untimely weeding hence, herbicides are an important but not the only weed control option under CA systems in Zimbabwe.

1. Introduction

Conservation agriculture (CA) is a crop management system being promoted in southern Africa due to its potential to conserve, improve and make efficient use of water and nutrients (FAO, 2002). CA is based on three principles: a) zero or minimum soil disturbance, b) maintenance of permanent organic soil cover and c) diverse crop rotations and associations (Kassam et al., 2009). Potential benefits of CA include reduced soil erosion and water run-off (Derpsch et al., 1986; Thierfelder and Wall, 2009), increased rainfall use efficiency (Thierfelder and Wall, 2009), early planting (Haggblade and Tembo, 2003), increased soil quality and biological activity (Thierfelder and Wall, 2010), and savings in on-farm labour (Sorrenson et al., 1998).

Smallholder farmers in southern Africa face a number of challenges including low income, insufficient technical knowledge, small land sizes (average of 2.1 ha) and poor farming equipment (Chamunorwa, 2010). The elimination of conventional tillage practices results in increased weeding pressure especially in the early years (Vogel, 1994b) and the need for effective weed control is limited by insufficient farm labour. No-tillage combined with residues under CA may also lead to a change in the micro-environment leading to a shift in weed flora intensifying the weed management problems (Derpsch, 2008).

Many smallholder farmers in Zimbabwe rely on manual weed control using hand hoes (Mandumbu et al., 2011), which is labour intensive and is slowed down by the presence of residues (Vogel, 1994b). Hand hoeing may require up to four weeding times during the cropping season for effective weed control (Mashingaidze et al., 2012). Therefore, there is need for effective weed control strategies that reduce labour requirement while being feasible within the farmers' circumstances. Weed management practices such as manual weeding and herbicides facilitate the decrease in weed

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

0261-2194/$ – see front matter
http://dx.doi.org/10.1016/j.cropro.2013.06.002

pressure (Norsworthy and Frederick, 2005). Integration of highly competitive green manure cover crops into the farming systems may also reduce weed pressure (Caamal-Maldonado et al., 2001). However, the availability of appropriate knowledge on integrated weed management is not available at farm level. Use of green manure cover crops e.g. velvet beans (*Mucuna pruriens* L.) is not perfectly adapted to the smallholder farmers' circumstances, as the grain cannot be easily consumed without significant processing.

Herbicides are a potential strategy for effective weed control under CA. Glyphosate [N-(phosphonomethyl) glycine], paraquat (1,1′-dimethyl-4,4′-bipyridinium), metalachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-2-methoxy-1-methylethyl) acetamide and atrazine (2-Chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) are readily available products at most chemical agro-input suppliers of Zimbabwe. However, most of these enterprises operate in urban areas which and cannot be easily accessed by farmers in remote areas. Some herbicides such as atrazine can be mixed with other herbicides (e.g. glyphosate and metalachlor). This increases the controlled weed spectrum and reduces herbicide failure.

Although the use of atrazine is relatively common and widely promoted under maize production, its residual effects are likely to affect the succeeding broadleaved crops (e.g. a legume crop following maize in a maize-legume rotation). In addition, the use of atrazine raised concerns over human and animal toxicity when it was found in drinking water but currently the cumulative risk assessment of this herbicide is not yet conclusive (Williams et al., 2010).

Few economic studies have been carried out to provide evidence and support the widespread use and feasibility of herbicides in CA under smallholder farmers' conditions in southern Africa. The objective of this study was to evaluate the effectiveness and economic benefits of manual and chemical weed control strategies under CA in Zimbabwe.

2. Materials and methods

2.1. Site description

The experiments were established at six sites; three on-station and three on-farm sites that receive rainfall in one main cropping season between November and March in a unimodal pattern. The sites generally have a long dry period (April to October) where April to July is cool and August to October is warm. All sites are in the Zimbabwean agro-ecological region II characterised by annual rainfall of between 700 and 1000 mm. Mean maximum daily temperatures during summer can exceed 32 °C. The region is suitable for intensive crop and livestock production.

2.1.1. Research station sites

CIMMYT-Harare (17°80′S, 31°50′E and 1503 m.a.s.l.), is a research station located at the University of Zimbabwe Farm on red clay soil, classified as *Chromic Luvisol*. The soils are characterised by high clay content of up to 40% and organic matter content with a pronounced granular structure (Nyamapfene, 1991). Domboshawa Training Centre (DTC) (17°37′S 31°10′E and 1560 m.a.s.l.) site is characterised by moderately deep *Arenosols* and *Luvisols* under FAO classification (Vogel, 1994b) that have 5% clay content and are derived from granite parent material. Henderson Research Station, HRS, (17° 34′S, 30° 54′E and 1136 m.a.s.l.) is on sandy soils (*Arenosols*) of poor fertility (>80% sand) derived from granite parent material (Thierfelder and Wall, 2009).

2.1.2. On-farm sites

The on-farm sites include Hereford farm (17°42′S, 31°45′E and 1077 m.a.s.l.), a former commercial farm located in Bindura district, characterised by heavy red clay soils of up to 40% clay content and rich in organic matter (Nyamapfene, 1991), classified as *Chromic Luvisols*. Madziva communal area (17°01′S, 31°41′E and 1181 m.a.s.l.) in Shamva district, is characterised by sandy soils classified as *Arenosols* derived from granite parent material (Thierfelder et al., 2012). Chikato School (17°19′S, 31°49′E and 1161 m.a.s.l.) also in Shamva district has *Chromic Luvisols* rich in clay and organic content. Farmers at all the three on-farm sites grow maize as a staple crop and some cash crops such as cotton (*Gossypium hirsutum* L.) and tobacco (*Nicotiana tabacum* L.). Cowpeas (*Vigna unguiculata* (L.) Walp), soyabeans (*Glycine max* (L.) Merr.) and groundnuts (*Arachis hypogaea* L.) are also common in these areas but grown on small pieces of land. Most of the farmers in these areas own small numbers of cattle and farming is their main source of livelihoods. Unconventional small-scale gold mining is widespread too as a source of income.

2.2. Description of experiments

2.2.1. On-station experiments

The experiments were established at three on-station sites in 2009–10 season. At all three sites, maize was grown under rain-fed conditions, no-tillage and 2.5 t ha^{-1}, maize residues uniformly spread in each plot. In 2009–10 season, the maize hybrid ZS261 (a medium maturing maize quality protein maize hybrid, which takes approximately 135 days to reach maturity) was planted at all sites which was changed in 2010–11 season to the maize hybrid Pristine 601 (a medium maturity hybrid which matures in 135 days after sowing). The change in variety was necessary because ZS261 was prone to maize streak virus. Each site had six treatments as follows:

a. Manual weeding with hand hoe only, whenever weeds were 10 cm tall or 10 cm in length for grasses with stoloniferous–rhizomatous growth habit (when weeds are still young, a common practice by smallholder farmers).
b. Paraquat at 1.0 l ha^{-1} (0.25 l ha^{-1} a.i (active ingredient)) at seeding plus manual weeding whenever weeds were 10 cm tall or 10 cm length of grasses with stoloniferous–rhizomatous growth habit.
c. Glyphosate at 2.5 l ha^{-1} (1.025 l ha^{-1} a.i) at seeding plus manual weeding whenever weeds were 10 cm tall or 10 cm length of grasses with stoloniferous–rhizomatous growth habit.
d. Atrazine at 3.6 l ha^{-1} (1.80 kg ha^{-1} a.i) at seeding plus manual weeding whenever weeds were 10 cm tall or 10 cm length of grasses with stoloniferous–rhizomatous growth habit.
e. Glyphosate + atrazine 2.5 l ha^{-1} (1.025 l ha^{-1} a.i) plus 3.6 l ha^{-1} (1.80 kg ha^{-1} a.i) respectively at seeding plus manual weeding whenever weeds were 10 cm tall or 10 cm length of grasses with stoloniferous–rhizomatous growth habit.
f. Glyphosate + atrazine + metalachlor 2.5 l ha^{-1} (1.025 l ha^{-1} a.i) plus 3.6 l ha^{-1} (1.80 kg ha^{-1} a.i) plus 1.0 l ha^{-1} (0.96 l ha^{-1}) respectively at seeding plus manual weeding whenever weeds were 10 cm tall or 10 cm length of grasses with stoloniferous–rhizomatous growth habit.

The experiment was laid out as a randomised complete block design (RCBD) with six treatments replicated three times at each experimental site. Maize received a basal application of 150 kg ha^{-1} (11 N, 21 P_2O_5 and 11 K_2O), and 150 kg ha^{-1} ammonium nitrate (52 N) applied as a top dressing, split applied at four and seven weeks after emergence.

2.2.2. On-farm experiments

Ten demonstration plots that were established in the 2004/05 season at the three on-farm sites were used in this experiment. The