

**Weed dynamics in low-input dryland smallholder conservation agriculture  
systems in semi-arid zimbabwe**

**by**

**Nester Mashingaidze**

**Submitted in partial fulfillment of the requirements for the degree  
PhD Agronomy  
In the Faculty of Natural & Agricultural Sciences  
University of Pretoria**

**Supervisor: Dr. I.C. Madakadze  
Co-Supervisor: Dr. S. Twomlow**

**February 2013**

## DECLARATION

I, Nester Mashingaidze declare that the thesis, which I hereby submit for the degree PhD Agronomy at the University of Pretoria, is my own work and has not previously been submitted by me at this or any other tertiary institution.

SIGNATURE: .....

DATE: .....

## ACKNOWLEDGEMENTS

I am grateful to my supervisors – Dr. I.C. Madakadze and Dr. S.J. Twomlow- for their patience and encouragement during the course of this study. I would also like to thank Prof. J. Nyamangara, Dr. L. Hove, Prof. Mafongoya, Dr. J. Storkey, Dr. W. Mupangwa and Prof. A.B. Mashingaidze for their invaluable contributions to this study. I am also thankful to Mr. R. Mandumbu, current and past ICRISAT staff especially Mr. B. Ncube. I am indebted to Mr. K. Muchaitei, Mrs. Mutukwa (Masvingo AGRITEX officers) and CARE International staff in Masvingo District for the assistance provided during the course of the study. My heartfelt thanks go to the farmers in Wards 12 and 14 of Masvingo District for allowing me to monitor their fields and the warm hospitality they extended to me during this study.

Financial support for the research is duly acknowledged from ICRISAT, the National Research Foundation (RSA) and the International Foundation for Science (IFS). Midlands State University provided support during thesis write up.

Finally, I would like to thank my mother Mrs. V. Mashingaidze, my husband Albert and my children Ruvarashe and Munashe. To Zira, Cecilia, Rumbi, Tari, Philbon, Steven, Nelson, my uncle LBD, Joana, the Mutetwa's, Sandy, Keba and my colleagues at Midlands State University your support was always appreciated!

Praise and glory to the Lord from whom all good things proceed!!

## CONTENTS

Title page	i
Declaration	ii
Acknowledgements	iii
Contents	iv
List of Tables	viii
List of Figures	x
List of abbreviations	xiii
Abstract	xiv
<b>CHAPTER 1 GENERAL INTRODUCTION</b>	<b>1</b>
1.1 Background	1
1.2 Rationale of study	5
1.3 Research questions	7
1.4 Outline of thesis	8
<b>CHAPTER 2 LITERATURE REVIEW</b>	<b>9</b>
2.1 Introduction	9
2.2 Smallholder agriculture in sub-Saharan Africa	10
2.2.1 Constraints to crop production	10
2.2.2 Crop production in the semi-arid tropics	11
2.3 Conservation agriculture	14
2.3.1 Principles of CA	14
2.3.2 Benefits associated with CA	21
2.3.3 Challenges to CA adoption	23
2.4 Weed dynamics under CA	26
2.4.1 Tillage effect on weeds	26
2.4.2 Crop residue mulching effects on weeds	32
2.4.3 Weed response to diversified crop rotations	33
2.5. Weed management in CA	35
2.6 Weed management in smallholder agriculture in Zimbabwe	38

2.7 Conclusion	40
<b>CHAPTER 3 CROP YIELD AND WEED GROWTH UNDER CONSERVATION AGRICULTURE IN SEMI-ARID ZIMBABWE</b>	<b>41</b>
3.1 INTRODUCTION	42
3.2 MATERIALS AND METHODS	43
3.2.1 Location	43
3.2.2 Treatments and experimental layout	44
3.2.3 Crop management	45
3.2.4 Data collection	47
3.2.5 Statistical analysis	48
3.3 RESULTS AND DISCUSSION	48
3.3.1 Seasonal rainfall	48
3.3.2 Weed density and biomass	50
3.3.3 Crop performance	62
3.4 CONCLUSION	66
<b>CHAPTER 4 RESPONSE OF WEED FLORA TO CONSERVATION AGRICULTURE SYSTEMS AND WEEDING INTENSITY IN SEMI-ARID ZIMBABWE</b>	<b>68</b>
4.1 INTRODUCTION	68
4.2 MATERIALS AND METHODS	70
4.2.1 Experimental design and crop management	70
4.2.2 Data collection	70
4.2.3 Statistical analysis	70
4.3 RESULTS AND DISCUSSION	71
4.3.1 Seasonal rainfall	71
4.3.2 General effects on weed species and density	73
4.3.3 Specific weed densities	73
4.3.4 Weed community diversity	87
4.4 CONCLUSION	89

CHAPTER 5 WEED COMPOSITION IN MAIZE (ZEA MAYS L.) FIELDS UNDER SMALLHOLDER CONSERVATION FARMING	91
5.1 INTRODUCTION	92
5.2 MATERIALS AND METHODS	93
5.2.1 Site description	93
5.2.2 Focus group discussion	94
5.2.3 Field study	95
5.2.4 End of season farmer-feedback workshop	101
5.3 RESULTS AND DISCUSSION	102
5.3.1 Seasonal rainfall	102
5.3.2 Adoption of CF practices by farmers	104
5.3.3 Weed dynamics	104
5.3.4 Maize grain yield	119
5.3.5 Farmer perceptions	121
5.4. Conclusion	125
CHAPTER 6 WEEDS IN COMPOST APPLIED IN SMALLHOLDER CONSERVATION FARMING	127
6. 1 INTRODUCTION	128
6.2 MATERIALS AND METHODS	129
6.2.1 Sample collection	130
6.2.2 Weed composition determination	131
6.2.3 Statistical analysis	132
6.3 RESULTS AND DISCUSSION	136
6.3.1 Effect of composting on weeds	132
6.3.2 Weeds in applied composts	138
6.4 CONCLUSION	145
CHAPTER 7 GENERAL DISCUSSION	147
7.1 Introduction	147
7.2 Conservation agriculture	147
7.2.1 Tillage effect on weed and crop growth	147



7.2.2 Maize residue mulch effect	150
7.2.3 Hoe weeding intensity	151
7.3 Conservation farming	152
7.3.1 Weeds in conservation farming	152
7.3.2 Influence of management practices	154
7.4 Conclusions	155
7.5 Recommendations for future research	157
REFERENCES	158
APPENDICES	186

## LIST OF TABLES

Table 2.1	The proportion of the total area under CA in the different continents (Adopted from Friedrich <i>et al.</i> , 2012)	24
Table 2.2	Labour requirements in three weeding systems commonly used by smallholder farmers in semi-arid Zimbabwe (Adopted from Ellis-Jones <i>et al.</i> , 1993)	39
Table 3.1	Tillage main effect on weed biomass in cowpea and sorghum grown at Matopos Research Station in 2008/09 and 2009/10 seasons	53
Table 3.2	Maize mulch rate main effect on weed density (m <sup>-2</sup> ) and biomass (kg ha <sup>-1</sup> ) in cowpea and sorghum grown at Matopos Research Station in 2008/09 and 2009/10 seasons	57
Table 3.3	Effect of hoe weeding intensity main effect on weed density (m <sup>-2</sup> ) and biomass (kg ha <sup>-1</sup> ) in cowpea and sorghum grown at Matopos Research Station in 2008/09 and 2009/10 seasons	61
Table 3.4	Response of cowpea yield to tillage, maize mulch rate and hand hoe weeding intensity at Matopos, Zimbabwe in 2008/09 season	64
Table 3.5	Sorghum yield response to tillage, maize mulch rate and hand hoe weeding intensity at Matopos, Zimbabwe in 2009/10 season	66
Table 4.1	Mean density of weed species (no. m <sup>-2</sup> ) found in the first 13 weeks in cowpea and sorghum crops grown at Matopos Research Station during the 2008/09 and 2009/10 seasons, respectively	75
Table 4.2	Effect of tillage main effect on cumulative density of weed species <sup>∞</sup> found in cowpea (2008/09 season) and sorghum (2009/10 season) in the first 13 weeks after planting (WAP) at Matopos Research Station	72
Table 4.3	Effect of maize mulch rate main effect on cumulative density of weed species <sup>∞</sup> found in cowpea (2008/09 season) and sorghum (2009/10 season) in the first 13 WAP at Matopos Research Station	80
Table 4.4	Effect of intensity of hand-hoe weeding main effect on density of weed species <sup>∞</sup> found in the first 13 WAP in cowpea (2008/09 season) and	84

	sorghum (2009/10 season) crops at Matopos	
Table 4.5	Richness (number of species per plot), diversity (Shannon's H' index) and evenness (Shannon's E index) for weed species present under different treatments in cowpea (2008/09 season) and sorghum (2009/10 season) crops grown at Matopos Research Station	89
Table 5.1	Number of fields under different tillage systems monitored during the 2008/09 season in wards 12 and 14 of Masvingo district	96
Table 5.2	Relative importance value (%) of weed species occurring in the sampled early summer seed bank under the different tillage systems in 2008 in Masvingo District.	105
Table 5.3	Weed community diversity for the early summer weed seed bank under different tillage systems in Wards 12 and 14 of Masvingo District in 2008	107
Table 5.4	Relative importance value (%) of weed species occurring above-ground in maize fields under different tillage systems during the 2008/09 season in Wards 12 and 14, Masvingo District. Weed species were ranked according to importance in CONV tillage	110
Table 5.5	Weed seedling density (m <sup>-2</sup> ) under maize of <i>A. hispidium</i> and <i>C. dactylon</i> under different tillage systems during different sampling periods in 2008/09 season in Wards 12 and 14 in Masvingo District	114
Table 5.6	Weed density within basin and in the inter-row area in maize grown under basin fields in Masvingo District in 2008/09	118
Table 5.7	Density of specific weeds <sup>oo</sup> within basin and in the inter-row area in maize grown under basin fields in Masvingo District in 2008/09	118
Table 5.8	Constraints to crop production ranked in order of importance by CONV tillage and PB farmers in Wards 12 and 14 of Masvingo District in November 2008	122
Table 5.9	Ranking of the five most abundant weeds in CONV and PB fields in Wards 12 and 14 of Masvingo District, August 2009	124
Table 5.10	The five most difficult to control weeds ranked by farmers in Wards 12 and 14 of Masvingo District in August 2009	125
Table 6.1	Relative importance value (%) of weed species occurring in fresh and	132

mature compost obtained from farms in Wards 12 and 14 of Masvingo District during 2009. Weed species are ordered according to abundance in immature compost

Table 6.2	Relative importance value (%) of weed species occurring in heap and pit stored composts applied on farms in 2009 in Wards 12 and 14 of Masvingo district. Weed species are ordered according to abundance in heap stored compost	138
Table 6.3	Weed emergence in heap and pit stored compost applied on farms in Wards 12 and 14 of Masvingo District during 2009/10 season	145

## LIST OF FIGURES

Figure 2.1	Fig. 2.1 The Natural Regions (NR) of Zimbabwe (Adopted from OCHA, 2009)	13
Figure 2.2	A diversified crop rotation to maintain soil fertility and break pest lifecycle (FAO, 2012)	21
Figure 2.3	The theoretical transition phases from conventional practice to CA (FAO, 2012b)	22
Figure 2.4	Proportion contributed to increased maize grain yields on smallholder farmers' CF fields in southern Zambia (Adopted from GART, 2008)	23
Figure 3.1	Cumulative daily rainfall received and the timing of crop management practices at Matopos, Zimbabwe in the 2008/09 and 2009/10 cropping seasons. W1, W2, W3 and W4: high intensity hoe weeding operations; W1 and W3: low intensity hoe weeding operations	49
Figure 3.2	Tillage x weeding intensity interaction on weed biomass at 4 WAP in cowpea grown in 2008/09 at Matopos, Zimbabwe. Narrow bars represent $\pm$ SED. Square root ( $x + 0.5$ ) transformed data presented. <i>Abbreviations:</i> CONV - Mouldboard plough; RT – Ripper tine; PB – Planting basins; SED - standard error of difference of the means	54
Figure 3.3	Tillage x maize mulch rate interaction on weed biomass at 4 WAP in sorghum at Matopos, Zimbabwe in the 2009/10 season. Narrow bars represent $\pm$ SED. Square root ( $x + 0.5$ ) transformed data presented. <i>Abbreviations:</i> CONV - Mouldboard plough; RT - Ripper tine; PB - Planting basins; SED - standard error of difference of the means	58
Figure 4.1	Daily rainfall received between November and March at Matopos Research Station during the A. 2008/09 (561.1 mm) and B. 2009/10 (499.5 mm) cropping seasons	72
Figure 4.2	Tillage x maize mulch rate interaction on total density of <b>A.</b> <i>U. panicoides</i> , <b>B.</b> <i>Setaria</i> spp. and <b>C.</b> <i>L. martinicensis</i> in cowpea (2008/09) and <b>D.</b> <i>S. pinnata</i> and <b>E.</b> <i>B. diffusa</i> in sorghum (2009/10) grown at	81

Matopos Research Station. Narrow bars represent  $\pm$  SED. Square root ( $x + 0.5$ ) transformed data presented. *Abbreviations*: CONV - Conventional mouldboard plough, RT - ripper tine, PB - Planting basin; SED - Standard error of difference of the means

- Figure 4.3 Tillage x weeding intensity interaction on total density of **A. M.** 85  
*verticillata*, **B. C. monophylla** and **C. A. Mexicana** in cowpea (2008/09)  
grown and **D. U. panacoides**, **E. B. pilosa** and **F. A. mexicana** in  
sorghum (2009/10) grown at Matopos Research Station. Narrow bars  
represent  $\pm$  SED. Square root ( $x + 0.5$ ) transformed data presented.
- Figure 4.4 Maize mulch rate x weeding intensity interaction on total density of **A. I.** 86  
*plebia*, **B. S. pinnata** and **C. Setaria** spp. in sorghum grown at Matopos  
Research Station. Narrow bars represent  $\pm$  SED. Square root ( $x + 0.5$ )  
transformed data presented. *Abbreviations*: SED -Standard error of  
difference of the means
- Figure 4.5 Maize mulch rate x weeding intensity interaction on total density of 87  
annual monocot species found in sorghum grown during the 2009/10  
season at Matopos Research Station. Narrow bars represent  $\pm$  SED.
- Figure 5.1 Mean timing of field operations in CONV tillage and CF fields in 103  
relation to cumulative rainfall received between 1 November 2008 and  
31 April 2009 in Wards 12 and 14 of Masvingo District. *Abbreviations*:  
CONV - mouldboard plough; PB – planting basin and HW - hoe weeding
- Figure 5.2 Relative density of weed species found in the early summer seed bank of 108  
fields under three different tillage systems in Wards 12 and 14 of  
Masvingo District in 2008. *Abbreviations*: CONV, mouldboard plough;  
PB3-, planting basin for 2 or 3 years; PB3+, planting basin for > 3 years
- Figure 5.3 Mean weed density in maize fields at different times during the 2008/09 112  
cropping season in Wards 12 and 14 of Masvingo district. Log ( $x + 1$ )  
data presented. *Abbreviations*: WAP - weeks after planting; CONV,  
mouldboard plough; PB3-, planting basin for 2 or 3 years; PB3+,  
planting basin for > 3 years
- Figure 5.4 A scatter-plot of the distribution of cumulative weed density ( $m^{-2}$ ) in 116

maize fields that had been under PB for different years in Wards 12 and 14 of Masvingo District during 2008/09 season. O (zero) years represents CONV tillage. *Abbreviation:* PB – planting basin; CONV tillage - conventional mouldboard plough

- Figure 5.5 Relationship between the number of years a field had been under PB and maize grain yield obtained from farms in Wards 12 and 14 of Masvingo District during the 2008/09 season. *Abbreviations:* PB – planting basin 120
- Figure 5.6 Relationship between weed density at 3 weeks after planting and maize grain yield obtained from farms in Wards 12 and 14 of Masvingo District during the 2008/09 season 120
- Figure 6.1 Farm x compost maturity interaction on the number of weed seedlings that emerged from composts obtained from farms in Wards 12 and 14 of Masvingo District during 2009/10 season. Narrow bars represent  $\pm$  SED. Log ( $x + 1$ ) transformed data presented 136
- Figure 6.2 Farm x compost maturity interaction on the number of weed seedlings of *E. indica*, *C. dactylon* and *A. hybridus* that emerged from composts obtained from farms in Wards 12 and 14 of Masvingo District during 2009/10 season. Narrow bars represent  $\pm$  SED. Log ( $x + 1$ ) transformed data presented 137
- Figure 6.3 Number of total, monocot and dicot weed seedlings that emerged from composts applied on different farms in Wards 12 and 14 of Masvingo District during 2009/10 season. Narrow bars represent  $\pm$  SED. Log ( $x + 1$ ) transformed data presented 140
- Figure 6.4 The number of weed seedlings of *E. indica*, *C. dactylon* and *A. hybridus* that emerged from composts obtained from different farms in Wards 12 and 14 of Masvingo District during 2009/10 season. Narrow bars represent  $\pm$  SED. Log ( $x + 1$ ) transformed data presented 141
- Figure 6.5 Relationship between period of heaping and weed seedlings in composted cattle manure applied on farms in Wards 12 and 14 of Masvingo District during 2009/10 season 143

## LIST OF ABBREVIATIONS

AGRITEX	Zimbabwe Department of Agricultural, Technical and Extension Services
ANOVA	Analysis of variance
CA	Conservation agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CONV	Conventional mouldboard plough tillage
FAO	United Nations Food and Agricultural Organization
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
GART	Golden Valley Research Trust
LSD	Least significant difference
MT	Minimum tillage
NGO	Non-Governmental Organisation
NR	Natural Region
OC	Organic carbon
PB	Planting basin
PRA	Participatory Rural Appraisal
REML	Restricted maximum likelihood model
RIV	Relative Importance Value
RT	Ripper tine
SED	Standard error of difference of means
WAP	Weeks after planting
ZCATF	Zimbabwe Conservation Agriculture Taskforce
ZFU	Zimbabwe Farmers' Union

## ABSTRACT

The reported requirement for a higher weeding effort due to increased weed infestations under conservation agriculture (CA) relative to conventional mouldboard plough tillage is perceived by both smallholder farmers and extension workers as the main limiting factor to the widespread adoption of CA by smallholder farmers in southern Africa. However, proponents of CA argue that weeds are only a problem under CA in the initial two years and decline afterwards resulting in reduced labour requirements for weeding under CA. They further posit that weeds are only major problem where minimum tillage (MT) is adopted without crop residue mulching and diverse crop rotations. This thesis explores the effect of time under CA on weed population dynamics and crop growth under the recommended CA practices and actual smallholder farmer practice in semi-arid Zimbabwe.

Assessment of weed and crop growth on a long-term CA experiment at Matopos Research Station revealed that the MT systems of planting basins and ripper tine were associated with higher early season weed density and biomass than conventional early summer mouldboard tillage (CONV) in both the fifth (cowpea phase) and sixth (sorghum phase) years of CA. This increased weed infestation within the first four weeks after planting in CA necessitated early weeding to provide a clean seedbed and avert significant crop yield loss. Maize mulching only suppressed early season weed growth in sorghum mostly at a mulch rate of  $8 \text{ t ha}^{-1}$  which is not a mulching rate that is attainable on most smallholder farms. However, the lower maize residue mulch rate of  $4 \text{ t ha}^{-1}$  was consistently associated with increased weed emergence and growth as from the middle of the cropping season in both crop species. The increased weed infestations under the mulch were probably due to the creation of 'safe sites' with moist conditions and moderate temperatures. The high weed growth under the mulch contributed to the low sorghum grain yield obtained under mulched plots. In addition, maize mulching was also associated with a less diverse weed community that was dominated by the competitive *Setaria* spp. and difficult to hoe weed *Eleusine indica* (L.) Gaertn. However, the weed community under CA was similar to that under CONV tillage with no evidence of a shift to the more difficult to control weed species. The increased early season weed growth and high weed pressure under CA meant that it

was still necessary to hoe weed four times within the cropping season to reduce weed infestations and improve crop growth even after four years of recommended CA practices. Early and frequent weeding was effective in reducing weed growth of most species including *Setaria* spp. and *E. indica* demonstrating that on smallholder farms where labour is available hoe weeding can provide adequate weed control. The wider spacings recommended for use in CA contributed to the low cowpea and sorghum grain yields obtained under CA compared to CONV tillage.

On smallholder farms in Masvingo District, the MT system of planting basin (PB) was the only conservation farming (CF) component adopted by farmers. There was no difference in the total seedling density of the soil weed seed bank and density of emerged weeds in the field in PB and conventional mouldboard ploughing done at first effective rains (CONV tillage). However, the first weeding in PB was done at least 15 days earlier ( $P < 0.05$ ) than in CONV tillage suggesting high early season weed growth in PB relative to CONV tillage. As weed density did not decline with time in PB, weed management did not differ with increase in years under PB. Shortage of inputs such as seed and fertiliser was identified by smallholder farmers as the most limiting factor in PB crop production with the area under PB was equivalent to the seed and fertiliser provided by CARE International for most farmers. On this small area, weeds could be managed by available family labour. Double the maize grain yield was obtained in PB (mean: 2856 kg ha<sup>-1</sup>) due to improved weed management and soil fertility. However, the use of poorly stored composts was found to introduce weeds into some PB fields. The findings of this study demonstrated that weed pressure was still high and weed management were still a challenge under the practice recommended to smallholder farmers in Zimbabwe even in the sixth year of practice. There is, therefore, a need for research on the economic feasibility of using herbicides, intercropping and optimal crop density to ameliorate the high weed pressure under CA.

**Key words:** Conservation agriculture, minimum tillage, maize residue mulching, hoe weeding intensity, weed density and biomass, weed species composition, cowpea (*Vigna unguiculata* (L.) Walp), sorghum (*Sorghum bicolor* (L.) Moench), maize (*Zea mays* L.)