CHAPTER 5

WEED COMPOSITION IN MAIZE (*ZEA MAYS* L.) FIELDS UNDER SMALLHOLDER CONSERVATION FARMING

ABSTRACT

Smallholder farmers in southern Africa have reported on increased labour requirements for hoe weeding due to high weed infestations in conservation farming (CF) fields. However, CF proponents claim that weed pressure and labour requirements for weeding decrease within the first three years under the recommended CF practices. An observational study was carried out during the 2008/09 cropping season on 21 maize fields in Wards 12 and 14 of Masvingo District to determine weed composition in fields that had been under CF for different years. Fields were grouped into CF3- (under CF for 2 or 3 years) and CF3+ (under CF for 4 or 5 years) with conventional mouldboard plough tillage (CONV tillage) used as the control group. Participatory Rural Appraisal (PRA) techniques were used to obtain farmer perception of the most limiting constraints in CF. Neither crop residue mulching to provide a soil cover of at least 30% soil cover at planting nor cereal/legume rotations had been practiced in the past four seasons by the 17 farmers reported to be practicing CF. The farmers had only adopted the minimum tillage system of planting basins (PB) and the associated improvements in management. Hereafter, the CF fields will be referred to as PB fields. Tillage had no significant effect on weed density and species composition. However, the first post-planting hoe weeding was done at least 15 days earlier ($P < 0.05$) in PB than in CONV tillage suggesting higher early season weed growth in PB relative to CONV tillage. Three post-planting weedings were carried out in PB compared to only two under CONV tillage. Farmer ranking of the main constraints in PB were low rainfall > input unavailability > labour > pests. It seemed that farmers were committing PB to small acreages equivalent to the inputs supplied by NGOs. Under these low areas, weeds could be managed by available family labour. At least double the maize grain yield was obtained from PB compared to CONV tillage (mean: 1 052 kg ha^{-1}) probably as a result of improvements in soil fertility and weed management. However, grain yield decreased with increase in weed density at 3 WAP highlighting the importance of early season weed control in maize. As labour requirements for weeding did not decline with time in PB, there is need to investigate the use of herbicides to reduce early season weeding burden on smallholder farms. Management practices such as the use of poorly composted manure may have contributed to the high weed infestations and introduced some new weed species in some PB fields.

Key words: Conservation farming, tillage system, on-farm, weed emergence, weed density

5.1 INTRODUCTION

In Zimbabwe, there has been wide-scale promotion of conservation farming (CF) to smallholder farmers that began in 2004 with about 5 000 households and by 2009 the number had increased almost to 100 000 (Marongwe *et al*., 2011). Conservation farming was promoted to farmers without draught animal power and enabled the farmers to plant early without the need for ploughing (Mazvimavi & Twomlow 2009). Improvements in planting date, fertility management and water harvesting have resulted in a doubling of the yields in CF compared to conventional plough tillage u (Twomlow *et al*., 2008). However, Mazvimavi et al. (2011) observed that the area under CF has remained low despite the marked yield increases under this practice. Marongwe *et al*. (2011) attributed the low CF adoption to increased labour especially for weeding.

The extent of adoption of the three principles of conservation farming (CF) and level of field management of CF fields by smallholder farmers is reported to differ between farmers (Mazvimavi *et al*., 2011). The majority of CF farmers are reported to be practicing only the minimum tillage system of planting basins. However, some farmers with more experience in CF have also begun incorporating crop residue mulching and crop rotation. Surveys done by ICRISAT showed that the CF component adopted differed with area and with farmer. Adoption of only planting basins is expected to lead to increased weed pressure and the development to control weed species. However, where CF is practiced with good management it is claimed that weed pressure will reduce after the first three years leading to reduced weeding effort over time. However, the level of soil cover and crop rotation sequence determine the level of weed infestations. Ribeiro *et al*. (2005) report that smallholder farmers in Brazil, despite rotating crops and retaining some soil cover, still struggle to control weeds under CA after more than 10 years. Information documenting weed population dynamics under CF as adopted by smallholder farmers in Zimbabwe is currently unavailable.

The objectives of this on-farm observational study are to:

1. Characterize the main form of CF adoption by smallholder farmers
2. determine weed infestation and composition in fields that had been under CF for different periods of time.
3. identify farmer perceptions on production constraints in CF.

5.2 MATERIALS AND METHODS

5.2.1 Site description

An observational field study was used to assess weed composition in CF fields and Participatory Rural Appraisal (PRA) techniques to identify farmer perceptions of constraints to CF in Ward 12 (30^{0} 53’ E, 20^{0} $30^{'}$ S; altitude of 1094 – 1101 m) and Ward 14 (31^{0} 09’ E, 20^{0} 20’ S,; altitude 1041 - 1087 m) of Masvingo District of Zimbabwe during the 2008/09 cropping season. Masvingo District is one area in semi-arid Zimbabwe where high CF adoption has been recorded among smallholder farmers, with the practicing farmers including those that were trained and provided with inputs for CF by CARE International as well as spontaneous adopters (Pedzisa *et al*., 2010*)*. Farmers in Wards 12 and 14 of Masvingo District have practiced CF for varying lengths of time and, thus, provided a chance to test the hypothesis that high weed infestations in CF were only confined to the initial two years. Observational studies were considered appropriate for this study as they are useful for determining changes in parameters of interest under actual farmer practices (Bullied *et al*., 2003; Lawson *et al*., 2006).

Masvingo District has an average annual rainfall of 582 mm with a range of 102 – 1 037 mm (Mugabe *et al*., 2004). However, about 7% of the district receives more moderate rainfall (650 – 800 mm per annum) and this includes the area around Lake Mutirikwi (FAO, 2009). Wards 12 and 14 are found within this relatively wetter area that is classified as Natural Region III by

Vincent & Thomas (1960). The rest of the district falls under Natural Region IV. The main rainy season is from mid-November to mid-March with mid-season dry spells commonly experienced between December and January. The mean summer and winter temperatures are 23^0C and 10^0C, respectively. Soils are of the fersiallitic type (Nyamapfene, 1991). Soil analysis was done in November 2008 on 23 fields that were monitored for weed growth during the 2008/09 season. The results indicated that the sandy loam soils in Wards 12 and 14 were relatively acidic with low nutrient status (mean pH (water) 5.1 ±0.70, organic carbon 1±0.33%, total N 0.1± 0.037% and total P 0.04±0.016%).

The major crops grown in Wards 12 and 14 are maize (*Zea mays* L.), groundnuts (*Arachis hypogea* L.), bambarra groundnut (*Vigna subterranean* (L.) Verdc), finger millet (*Eleusine coracana* Gaertn.) and sweet potato (*Ipomea batatas* L.) Other crops include cowpea (*Vigna unguiculata* (L.) Walp), sunflower (*Helianthus annum* L.), sugar beans (*Phaseolus vulgaris* L.), sorghum (*Sorgum bicolor* (L.) Moench), pearl millet (*Pennisetum glaucum* (L.) R.Br.), water melon (*Citrullus lanatus* var. *lanatus* Thunb), cow melon (*Citrullus lanatus* var. *citroides* Thunb) and sweet sorghum (*Sorghum vulgare* Pers.). Crops such as cowpea, pumpkin, melons and sweet sorghum are grown as minor crops in maize and groundnut fields. Most farming systems are mixed crop/livestock systems with varying amounts of livestock such as beef cattle, goats and pigs kept.

5.2.2 Focus group discussion

Prior to the field study, focus group discussions were conducted in November 2008 in each ward. To select farmers who participated in FGD, a list of all farmers in the ward compiled by the AGRITEX officer was used to group farmers according to adoption or non-adoption of CF since its inception in 2004. This gave two groups, the CF and non-CF farmers. For the non-CF group, 20 farmers were randomly selected and invited to attend an FGD at the local ward meeting place on an appointed date. The CF group was further stratified into early and late adopters of CF and ten farmers were randomly selected from each group and invited to attend a separate FGD. The two FGD meetings were conducted on the same day but at different times per ward. The aim of the focus group discussion was to get a view of farmers' perceptions of constraints to crop production in CONV tillage and CF. Each focus group discussion lasted about 2 hours. In Ward 14, two separate focus group discussions were conducted and were attended by 16 non-CF and 15 CF farmers. However, in Ward 12 over 100 farmers were found assembled at the meeting point. The large turnout of mostly non-CF farmers may have been based on the farmers' hope that the meeting was convened for selection of new CF farmers by CARE International who would then be provided with inputs for use on CF fields. Due to the large number of participants and wet conditions on the day, only a single discussion was held in Ward 12. During each focus group discussion, notes were recorded on flip charts by the facilitator (researcher) and in a notebook by the co-facilitator (extension officer).

5.2.3 Field study

Farmers whose fields were monitored during the 2008/09 season were drawn from the sample of farmers that attended the focus group discussion in each ward. During the FGD, interested farmers were invited to participate in the study. From the group of interested non-CF farmers, farmers were selected based on the presence of field that had been under the same method of conventional tillage for a minimum of 5 years, farmer had not adopted CF on any of their fields in the previous seasons and field accessibility. In both wards, the majority of non-CF farmers used mouldboard ploughing tillage with some farmers without draught animal power using traditional hand hoe tillage. Six non-CF farmers (three per ward) were selected and the fields that were monitored ranged in size from 0.1 to 0.6 ha. Most of the fields monitored were outer fields that in the past four years (2005-2008) had had a two-year maize-groundnut rotation The majority of farmers used the ox-drawn Zimplow® VS200 mouldboard plough to prepare fields in early summer with planting done using third furrow planting. The decision to use farmers who had not previously adopted CF before was based on the observation that farmers that adopted a technology usually changed some of their traditional practices to those used in the new technology (Romney *et al*., 2005; Pedzisa *et al.*, 2010). This group is hereafter referred to as CONV tillage.

Since equilibrium after change in cultural practices including tillage usually occurs after the third year of practice (SWOARC, 1990; Ekboir, 2002) and high weed pressure under CF is believed to decline after three years (FAO, 2012), CF farmers were placed in two groups based on the number of years the field had been under CF. Those with 2 or 3 years' experience with CF comprised the first group and farmers with greater than 3 years of CF experience the other group. For CF, the years a field had been under CF, field accessibility, farmer willingness to participate and CF fields that had not been used as demonstration or experimental plots by CARE, ICRISAT or the extension officer were important considerations in selecting fields to be monitored. The fields that had been under CF for three years or less was viewed as being in the transition phase from CONV tillage practices to CF and is hereafter referred to as CF3-. The size of CF3- fields was 0.1 ha in Ward 12 and 0.05 ha in Ward 14 with the majority (78%) of fields were located close to the homestead. Fields where CF was practiced for more than three years were viewed as fields where CF was well established is hereafter referred to as CF3+. The size of fields was 0.1 ha in Ward 12 and 0.05 ha in Ward 14 as for the CF3- group. There was equal distribution of homestead and outer fields in the PB3+ group. A total of 23 farmers were selected with one of the farmers having both CF and CONV tillage fields to give a total of 24 fields (Table 5.1). In this study, all management decisions were determined by the farmer while the role of the researcher was to record operations and collect weed and crop data.

Table 5.1 Number of fields under different tillage systems monitored during the 2008/09 season in wards 12 and 14 of Masvingo district

Tillage	No. of fields in Ward		
	12	14	Total
CONV	3	3	6
PB3-	6	3	9
PB3+	3	6	9
Total			24

5.2.3.1 Soil weed seed bank

Soil samples were collected from the 24 fields from Wards 12 and 14 in mid-November 2008 before the onset of effective rains and the resultant first weed flush. A sampling net plot was demarcated in each field at least 2 m from the field border and two crossing diagonal transects were marked out. Four quadrats measuring 1 m x 1 m and spaced 5 m apart were aligned along each transect (Plate 5.1) to give 8 quadrats per field.

Plate 5.1 Soil sampling in CF farmer's field in Ward 14 of Masvingo District in November 2008.

In CONV tillage, one soil core (5.2 cm diameter and 15 cm depth) was obtained from one random position within each quadrat. Each soil core was separated into 0 - 5; 5 - 10 and 10 - 15 cm layers and the eight cores from the same depth were bulked to give three soil samples per CONV tillage field. This gave a cumulative surface area of ~ 170 cm^2 (volume 850 cm^3) sampled per field. In CF fields, quadrats were aligned so as to include four planting basins within the area to be sampled. Two soil cores were obtained per quadrat, one from within a randomly selected planting basin and the other soil core from the inter-row area adjacent to the basin. The soil cores from each sampling position (planting basin or inter-row area) were separated by soil depth (0 - 5; 5 - 10 and 10 - 15 cm) to give six soil samples per CF field. The cumulative surface area per sampling position in each CF field was the same as that in CONV tillage fields.

The 126 soil samples were partially air dried and clods broken after which the samples were stored in a cold room at 4 ^{0}C at Matopos Research Station until analysis. In December 2008, a sub-sample of 300 g was obtained per soil sample for weed seed bank analysis. Of the remainder, 50 g of the soil per field was sent for analysis of pH (water), % organic carbon; % total N and % total P using the standard methods outlined by Anderson and Ingram (1993). The weed seed bank was analysed using the seedling emergence method, which, although it can underestimate the absolute seed bank (Kellerman, 2004) provides a relative comparison to assess tillage effects (Carter & Ivany, 2006). Plastic pots (11.5 cm x 12 cm x 15 cm) were filled with silica sand and topped with the 300 g of sampled soil. The pots were watered and emerged weed seedlings were counted daily. Once counted weeds were removed to prevent self-seeding. Every fourth week, the soil was stirred to encourage weed germination and emergence. The experiment was terminated at the end of 16 weeks when there was no seedling emergence for three consecutive weeks.

Weed seed bank data analysis

Viable and non-dormant weed seed population per soil depth for each field was estimated by summing the number of seedlings counted over 16 weeks. The seedling numbers were then converted to weed density m^{-2} based on a 5.2 cm sampling core diameter. Relative importance values (RIV) were computed as the mean of the percentage relative density and relative frequency for each weed species (Chikoye & Ekeleme, 2001) per tillage system. Relative density (%) was calculated as the mean density of each weed species divided by the total weed density for that tillage system multiplied by 100. Relative frequency (%) was calculated as the frequency of individual weed species within each tillage system divided by the total frequency of all weed species in that tillage system multiplied by 100.

Seedling emergence (m^{-2}), species richness, Shannon's evenness and diversity index was calculated for each field. Shannon-Weiner' diversity index $H^{'}$ was calculated for each field after Magurran (1988) as follows:

$$H^{'} = (N \ln N - Sum\ (n \ln n)) / N \qquad \textit{Equation 1}$$

where $H^{'}$ measures species diversity through proportional abundance of species, with a higher value signifying greater diversity; N is the total population density m^{-2} and n is the population of each weed species found in this area;

and evenness index E

$E = H^{'} / \ln N$ *Equation 2*

where E is the relationship between the observed number of species and total number of species, with a greater value indicating greater uniformity between species abundances.

Seedling emergence data was square-root $(x + 0.5)$ transformed to homogenize variances (Gomez & Gomez, 1984). Weed data from the inter-row samples was used to determine tillage and soil depth effects on weed seed bank size and composition. In CF fields, sampling position (samples obtained from within planting basin and the inter-row area) and soil depth were the treatment factors in the seed bank analysis. The seedling emergence (m^{-2}), species richness, Shannon's evenness and diversity index data was subjected to an Unbalanced ANOVA (GenStat Release 9.1) and means were separated using the least significant difference (LSD) at $P < 0.05$.

5.2.3.2 Above-ground weed flora

Weed composition and density were estimated from the 24 experimental fields from Ward 12 and 14 during the period from November 2008 to April 2009. All weeds that were present in each of the 8 quadrats that had been used for soil sampling in November 2008 were identified to species level and counted. Thereafter, one quadrat from each diagonal transect was marked out with tall pegs and maintained as a permanent quadrat for weed assessments throughout the 2008/09 cropping season. Originally, weeds were to be sampled before each hoe weeding operation but since timing of weeding varied with farmer this approach was found to be difficult to implement. Furthermore, during the second weed survey some CF farmers reported that they had delayed weeding their fields until after the weed counts had been done and thus, this approach was interfering with farmer weed management. To avoid this, farmers were advised to weed their fields except for the area under the permanent quadrats. As from the third weed survey, weed counts were done when about 50% of farmers were observed to be weeding their fields and in this way weed counts were done during the main weeding period.

In addition to the weed count done at seed bank sampling, weed counts were done at 3, 7, 11 and 19 weeks after planting (WAP) based on the median planting date. In CF fields, weed counts were done separately for area within the planting basin and inter-row area per quadrat. The average planting basin area per field was recorded in November 2008 during the first weed count using basins within the eight quadrats. Field operations were recorded in a record book by farmers with the assistance of the extension officer. Farmers were also requested to record the time that they allocated to each weeding operation in monitored field. Daily rainfall was recorded during the season and crop yields were measured at harvesting.

Field data analysis

Farmers planted maize and groundnuts in fields during the 2009/10 season. However, only one CF farmer grew groundnuts compared to two in CONV tillage. Due to the low number of fields with groundnuts under CF, only the data from maize fields (n=21) was analysed. Weed density (m^{-2}) at soil sampling and 3, 7, 11 and 19 WAP and cumulative weed density after planting (3 to 19 WAP) were determined for each field during the 2008/09 cropping season. Relative importance values were computed for each weed species. Weed density data was log ($x + 1$) transformed to homogenize variances and the data was analysed for tillage effects and in CF sampling position effects.

A comparison of seed bank and above-ground weed floral composition was done using Sorenson's index of similarity (CC) as follows

$$CC = [2a/(2a+b+c)]/100 \qquad \text{Equation 3}$$

where a = number of species in common to the weed flora and seed bank in field *x*
b = total number of species present in seed bank in field *x*
c = total number of species present in the above-ground weed flora in field *x*

A higher index indicates strong similarity between seed bank and above-ground weed flora (Chikoye & Ekeleme, 2001).

Weed density and similarity indices were subjected to an Unbalanced ANOVA with Ward as the blocking factor as a prior analysis of weed density data using the residual maximum likelihood model (REML) method had indicated that the random variable Ward had a greater variance component than any of the management factors that differed across fields. These procedures were done using GenStat Release 9.1. For maize grain yield, REML was used to analyse the effect of tillage on crop grain yield. The REML method was used as it accounts for more than one source of variation. Random variables that had a significant relationship with maize grain yield were used to build the REML model as the random model. The structure of the REML model finally used in the analysis of maize grain yield was:

Response variate:	Maize grain
Fixed model:	Constant + Tillage system
Random model:	% manure use + number of weedings

Weed density, similarity index and maize grain yield means were separated using LSD at $P < 0.05$.

5.2.4 End of season farmer-feedback workshop

At the end of the 2008/09 cropping season a one-day workshop was held in August 2009 at Great Zimbabwe Hotel in Masvingo District. Twenty-two of the farmers whose fields had been monitored, the two extension officers and two CARE agronomists attended the workshop. Among the workshop objectives was for farmers to identify, using photographs, weed species found in farmers' fields and indicate whether any weed species were beneficial. Afterwards, farmers were divided into two equal sized groups of CONV and CF farmers and each group was asked to use pair wise ranking to list the most abundant weed species (Plate 5.2). The exercise was facilitated by the extension officers and CARE agronomists. The final activity was for all farmers to ranks weeds in terms of how difficult they were to control using hoe weeding.

Plate 5.2 Farmers in CF group using pair wise ranking to determine most abundant weed species in CF fields at Great Zimbabwe Hotel, Masvingo District in August 2009

5.3 RESULTS AND DISCUSSION

5.3.1 Seasonal rainfall

A total rainfall of 602 mm was received between November 2008 and April 2009 (Fig. 5.1) which was within the range expected for this part of Masvingo District (FAO, 2009). There was an early onset of the rains with 31 mm recorded on 9 November 2008 (Day 10 in Fig. 5.1). The rains, however, ceased after three days and a dry spell was experienced for five weeks. The dry soil conditions led to poor crop establishment in CF where all fields had been planted with the first rains. As a result, some (35%) CF fields had to be re-planted in mid-December 2008 when rains resumed on 15 December 2008 (day 44). In CONV tillage, only one field was winter ploughed in July 2008 and maize was planted with the first rains in this field. Of the fields that were ploughed in the summer, ploughing with the first rains was done in only one field where groundnut was initially planted. However, crop establishment was poor in these early planted crops such that farmers planted another crop within the first crop. This resulted in a maize-sorghum intercrop in winter-ploughed field and a maize-groundnut intercrop in fielded ploughed with first rains. The two remaining CONV tillage fields were ploughed and planted to maize in late December 2008 after the rains were well established. In general, CF farmers planted maize at least 11 days earlier than CONV tillage farmers during the 2008/09 cropping season. Rainfall was well distributed from late December 2008 and no mid-season dry spells were experienced between January and February 2009. Hoe weeding commenced earlier and was done more frequently (thrice) in CF compared to CONV tillage (twice). However, no additional weeding was done after the third weeding in CF during the 2008/09 cropping season (Fig. 5.1).

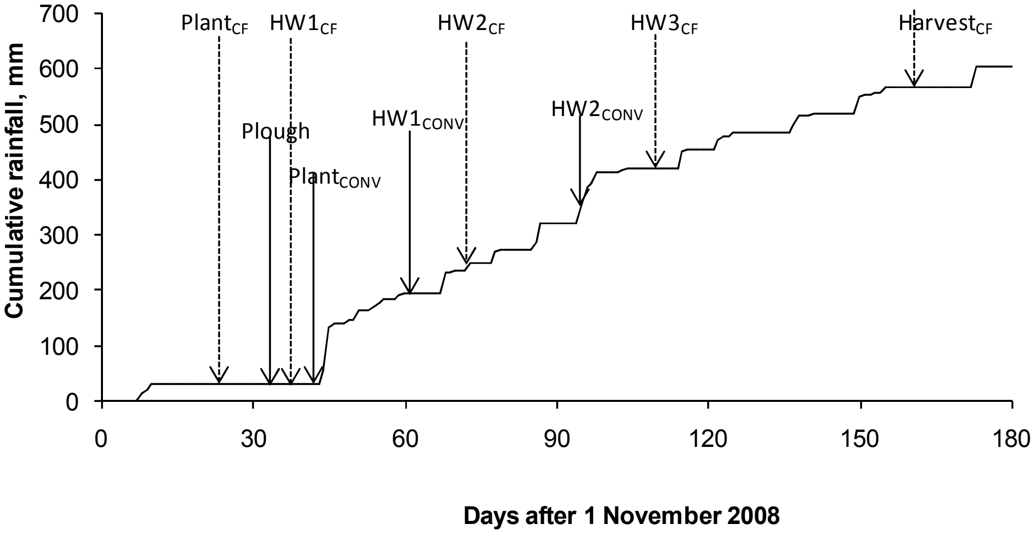

Fig. 5.1 Mean timing of field operations in CONV tillage and CF fields in relation to cumulative rainfall received between 1 November 2008 and 31 April 2009 in Wards 12 and 14 of Masvingo District. *Abbreviations*: CONV - mouldboard plough; CF - conservation farming and HW - hoe weeding

5.3.2 Adoption of CF practices by farmers

None of the monitored CF farmers whose fields were planted to maize during the 2008/09 season maintained a soil cover of at least 30% at planting. In the past four seasons all the CF farmers (n =17) had practiced maize monocropping on their CF fields. The only CF principle adopted by the monitored farmers was planting basin (PB) tillage for lengths of time varying from two to five years. Due to partial adoption of CF, the farmers previously referred to as CF3- and CF3+ will, hereafter, be referred to as PB3- and PB3+ , respectively.

5.3.3 Weed dynamics

5.3.3.1 Soil weed seed bank

Tillage system and soil depth did not have significant ($P > 0.05$) effects on total seedling density and density of individual weed species in the early summer soil weed seed bank of fields in Wards 12 and 14 during the 2008/09 cropping season. Tillage, however, had a significant ($P < 0.05$) effect on Shannon's weed species evenness (E) and diversity (H'). There was no significant ($P > 0.05$) tillage system x soil depth interaction on weed seedling density and seed bank community diversity. In the PB system position of sampling, PB years, soil depth and their 2-way and 3-way interactions did not have significant ($P > 0.05$) effects on weed seed bank size and composition.

5.3.3.1.1 Seed bank structure

A total of 18 weed species was identified in the soil seed bank with 8 weed species present in the CONV tillage seed bank compared to 14 species in each of the PB 3- and PB 3+ seed banks (Table 5.2). The annual monocot *E. indica* had the highest relative importance value (RIV) regardless of tillage system. After *E. indica*, the ranked order of weed species varied with tillage system. The grass weed *Cynodon dactylon* was the third most important species in the PB3- seed bank but was less important (RIV < 10) in CONV tillage and PB 3+. The fields that had been under PB for the longest time had *Galium spurium* as the second most important weed species in the seed bank suggesting that this weed may becoming more important with time under PB. The weed *Eragrostis aspera* that was absent from CONV tillage seed bank was a moderately important weed in the PB seed bank. The weed seed bank community under PB comprised a number rare (RIV < 10) weed species that were absent from CONV tillage seed bank (Table 5.2). The difference in importance of several weed species in the seed bank community under CONV and PB tillage systems may be suggestive of changes in weed seed bank community diversity.

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. Weed species ranked according to importance in CONV tillage

Latin name	Growth form[a]	RIV (%) in tillage system		
		CONV	PB3 -	PB 3+
Eleusine indica (L.) Gaertn.	Annual monocot	55.6	55.2	51.5
Cyperus esculentus L.	Perennial monocot	27.3	32.2	29.5
Richardia scabra L.	Annual dicot	19.0	17.5	21.2
Leucas martinicensis (Jacq.)R.Br.	Annual dicot	17.8	11.9	29.0
Galium spurium L. ssp. *africanum* Verdc	Annual dicot	11.8	13.6	30.5
Cynodon dactylon (L.) Pers.	Perennial monocot	9.0	23.6	5.8
Hibiscus meeusei Exell	Annual dicot	8.9	18.0	5.8
Phyllanthus leucanthus L.	Annual dicot	8.9	-	5.8
Eragrostis aspera (Jacq.) Nees	Annual monocot	-	17.8	11.7
Sida alba L.	Perennial dicot	-	11.7	-
Amaranthus hybrius L.	Annual dicot	-	5.8	-
Corchorus tridens L.	Annual dicot	-	5.8	5.8
Gnaphalium pensylvanicum Willd	Annual dicot	-	5.8	-
Ipomea plebia L.	Annual dicot	-	5.8	-
Solanum incanum L.	Perennial dicot	-	5.8	5.8
Acanthospermum hispidum DC.	Annual dicot	-	-	5.8
Cleome monophylla L.	Annual Dicot	-	-	5.8
Commelina benghalensis L	A/P monocot	-	-	5.8

A '-' indicates that a weed species was absent in a given tillage system; [a]A/P: annual / perennial. *Abbreviations:* CONV, moudboard plough; PB3-, planting basin period of 2 or 3 years; PB3+, planting basin for > 3 years

5.3.3.1.2 Tillage effect

There was no evidence of a decline in the total seedling density of the soil weed seed bank with years under PB as seed bank size did not differ ($P > 0.05$) between CONV and PB tillage systems. The upper 15 cm soil weed seed bank was estimated 422 seedlings m^{-2} for CONV tillage, 760 seedlings m^{-2} for PB3- and 655 seedling m^{-2} in PB3+. There was also no difference in weed seed distribution through the 15 cm soil layer between CONV and PB systems. In all tillage systems most weed seed was found in the upper 10 cm soil layer. Tillage, however, had a significant ($P < 0.05$) effect on weed seed bank diversity with a two-fold increase in the Shannon's evenness and diversity indices recorded in the PB seed bank compared to that under CONV tillage (Table 5.3). This indicated an increase in weed diversity in CF systems relative to CONV tillage although the length of time a field had been under PB had no significant effect on seed bank diversity.

The greater diversity in the PB seed bank was probably due to the wider ranger of weed species in PB relative to CONV tillage (Fig. 5.2). Although the nine additional weed species found in the PB seed bank had low relative importance values their increased relative density in PB (Fig. 5.2) probably contributed to the more equitable distribution of species and higher weed diversity in PB compared to the CONV tillage seed bank (Table 5.2). The presence of these rare species only in the PB seed bank may suggest that the PB system or cultural practices associated with PB may be introducing seeds of the rare weed species to the soil seed bank. The presence of *Amaranthus hybridus* and *Corchorus tridens* in the PB seed bank only (Table 5.2) suggests that these weed species may have been introduced by application of manure as the species were found to be usually abundant in poorly cured manure by Rupende *et al*. (1998). The higher weed seed bank diversity in PB may, if reflected on the above-ground flora, facilitate weed control in PB. According to Miyazawa *et al*. (2004) high weed community diversity may enhance competition among weed species and prevent the dominance of a single weed species especially if this is a problem weed in arable fields. This would result in reduced weed/crop competition if problem weed species is replaced by less competitive weed species.

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

Tillage system	Shannon's	
	Evenness (E) index	Diversity (H') index
CONV	0.30	0.31
PB3-	0.68	0.60
PB3+	0.65	0.81
LSD $_{(0.05)}$	0.320	0.379

Abbreviations: CONV, mouldboard plough; PB3-, planting basin for 2 or 3 years or less; PB3+, planting basin for > 3 years. LSD - least significant different; ns - not significantly different.

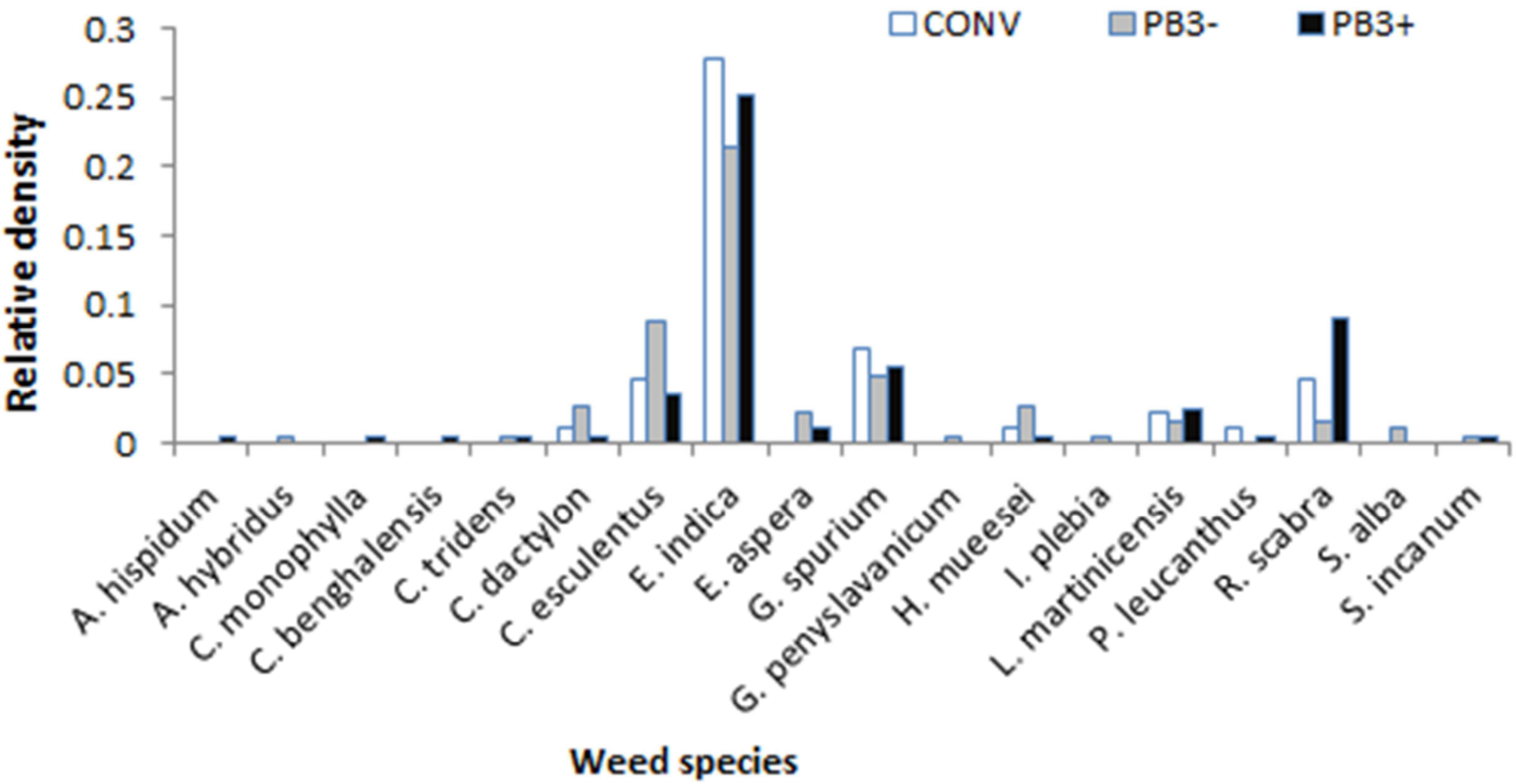

Fig. 5.2 Relative density of weed species found in the early summer seed bank of fields under three different tillage systems in Wards 12 and 14 of Masvingo District in 2008. *Abbreviations:* CONV, mouldboad plough; PB3-, planting basin for 2 or 3 years; PB3+, planting basin for > 3 years

5.3.3.2 Above-ground weed flora

5.3.3.2.1 Weed composition

Nineteen weed species were identified in maize fields during the 2008/09 season (Table 5.4) of which 15 species were also found in the soil seed bank (Table 5.2). However, *B. pilosa, D. stramonium, Digitaria* spp. and *S. asiatiaca* were not identified in seed bank while *S. alba* was not sampled in any of the fields during the maize growing period. The weed species *S. asiatica* was not present in the weed seed bank because there was no cereal host in the plastic pots used for seed bank enumeration. Most of the species that were not common to both seed bank and above-ground weed flora were usually identified in only one tillage system. Furthermore, the weed species had low RIVs showing that they were not generally important weed species in the study area. The ranking of the top five weed species based on RIV was influenced by tillage system. The top three weed species varied with tillage system but were found in all the tillage systems. In CONV tillage fields*, R. scabra* (73%) was the most important species followed by *C. dactylon* and both *L. martinicensis* and *A. hispidum*. In PB3- fields, *A. hispidum* had the highest RIV (62%) followed by *L. martinicensis* and *R. scabra*. The most important weeds in PB3+ were *R. scabra* (64%), followed by *L. martincensis* and *A. hispidum*.

However, the weed species *E. indica* which was the most important in the seed bank (Table 5.2) was not among the three most important weeds in the above-ground weed flora (Table 5.4) although it was still an important weed in all the tillage systems. In the seed bank, *A. hispidum* was identified only in PB3+ and had an RIV of less than 10 (Table 5.2) but in the field this weed was among the most important weed species in all the tillage systems. Such differences in the representation of weeds in the seed bank and above-ground flora were a reflection of the low Sorenson' similarity index recorded. All tillage systems had low similarity index of below 25 which indicated a weak relationship between weed species in above-ground flora and seed bank. This poor correlation in weed flora in soil seed bank and above-ground was also observed in studies by Chikoye and Ekeleme (2001) and Kellerman (2004) among others. Swanton and Booth (2004) state that the weed seed bank is at best a weak predictor of present above-ground flora as the transition from seed to seedling and finally to mature plant depends on many factors that may have varied between fields and the uncontrolled glasshouse where the seedling emergence method was used for weed seed bank estimation.

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

Latin name	Growth form	RIV (%) in Tillage system		
		CONV	PB3-	PB3+
Richardia scabra L.	Annual dicot	72.9	55.1	63.7
Cynodon dactylon (L.) Pers.	Perennial monocot	62.2	29.7	20.8
Acanthospermum hispidum DC.	Annual dicot	53.0	61.9	52.0
Leucas martinicensis (Jacq.)R.Br.	Annual dicot	53.0	55.2	60.4
Hibiscus meeusei Exell	Annual dicot	51.9	46.7	15.2
Ipomea plebia L.	Annual dicot	38.9	14.3	47.7
Eleusine indica (L.) Gaertn.	Annual monocot	28.0	33.9	44.9
Digitaria spp.	Annual monocot	26.2	11.4	12.4
Commelina benghalensis L	A/P monocot	25.8	29.7	40.2
Cyperus esculentus L.	Perennial monocot	13.0	5.9	13.1
Eragrostis aspera (Jacq.) Nees	A/P monocot	12.6	5.6	-
Galium spurium L. ssp. *africanum* Verdc	Annual dicot	12.6	5.6	19.2
Gnaphalium pensylvanicum Willd	Annual dicot	12.5	5.9	37.7
Amaranthus hybridus L.	Annual dicot	-	11.2	29.1
Bidens pilosa	Annual dicot	-	11.2	-
Cleome monophylla L.	Annual Dicot	-	5.6	25.1
Striga asiatica L.	Annual dicot	-	5.6	12.5

A '-' shows that weed species was absent in a given tillage system; A/P: annual or perennial; *Abbreviations:* CONV, mouldboard plough; PB3-, planting basin for 2 or 3 years; PB3+, planting basin for > 3 years

5.3.3.2.2 Weed density

There was no significant (P > 0.05) difference in the weed density measured in maize fields under different tillage systems during the 2008/09 cropping season (Fig. 5.3). The lack of a tillage effect on weed density differs from findings from other research done in southern Africa where MT systems were associated with increased weed density especially early in the cropping season (Mabasa *et al*., 1998; Muliokela *et al*., 2001; Mashingaidze *et al*., 2009b; Chapter 3). The lack of significant differences in weed emergence early in the 2008/09 cropping season between PB and CONV tillage fields in Wards 12 and 14 of Masvingo District may have been influenced by differences in weed management between the tillage systems.

The PB farmers in Wards 12 and 14 performed the first hoe weeding earlier than in CONV tillage fields (Fig. 5.1). The majority (53%) of PB fields were hoe weeded within the first week after maize was planted compared to CONV tillage where hoe weeding began three weeks after planting. As a result, the first hoe weeding was done at least 15 days earlier ($P < 0.05$) in PB compared to CONV tillage during the 2008/09 cropping season. The early weeding in CF is suggestive of high weed pressure soon after planting in these fields. Bullied *et a*l. (2003) reported that MT systems may be associated with earlier weed emergence than conventional plough tillage. Research done by Shumba *et al*. (1992) and Vogel (1994) demonstrated higher weed growth soon after planting in MT systems relative to conventional plough tillage that necessitated earlier and more frequent weeding in MT systems compared to conventional tillage. As the area under the quadrats was weeded during the first hoe weeding in the majority of PB fields, the early weeding in PB probably masked any differences in weed density at 3 WAP between PB and CONV tillage. A high level of weed management has been found to diminish the differences in weed infestation between tillage systems (Locke *et al*., 2002; Chapter 3). However, the findings of this study are not conclusive it may be that PB farmers were following the CF recommendations of frequent weeding with the aim of maximising maize yield in these PB fields that received both organic and inorganic fertilisers. There is need for further weed assessments that are carried out before farmers hoe weed their fields to determine whether PB fields are associated with higher early season weed infestations than CONV tillage.

There was no significant ($P > 0.05$) difference in timing and frequency of hoe weeding between PB3- and PB3+ farmers during the 2008/09 season implying that labour requirements in PB3+ had not yet gone down even after five years of PB. Since maize residue mulching offered limited weed suppression and resulted in increased weed growth under CA (Chapter 3 and 4), there is a need to investigate the use of herbicides to reduce the labour bottlenecks experienced early in the cropping season for CF farmers. One option for reducing the costs associated with herbicide use could be banding of herbicides. Previous work done in maize grown under ripper tine on smallholder farms in Zimbabwe demonstrated that labour for hoe weeding could be significantly reduced through either full cover or banded application of 50% of the recommended rate of atrazine (Gatsi *et al*., 2001). Positive returns to land, labour and draught animal power were obtained for application of atrazine in maize grown under ripping in this case.

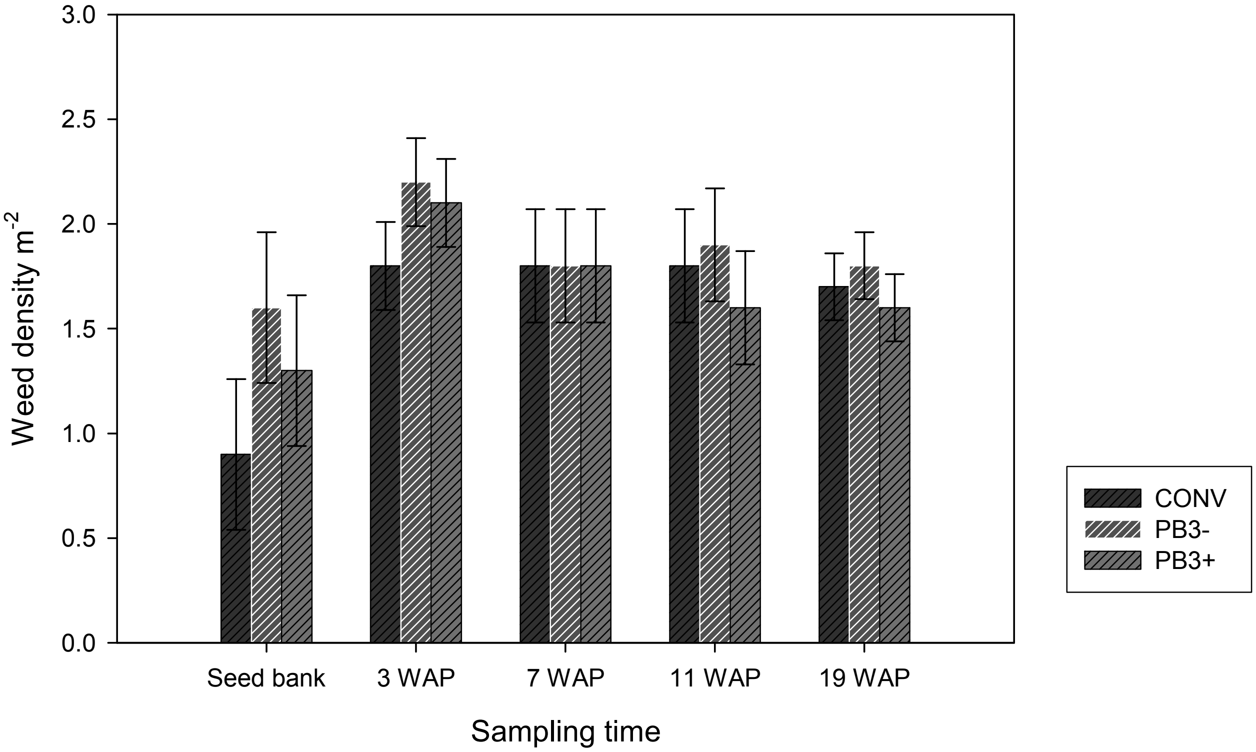

Fig 5.3 Mean weed density in maize fields at different times during the 2008/09 cropping season in Wards 12 and 14 of Masvingo district. Log (x + 1) data presented. Narrow bars present ±sed *Abbreviations*: WAP - weeks after planting; CONV, mouldboard plough; PB3 planting basin for 2 or 3 years; PB3+, planting basin for > 3 years

Although there was no significant difference in weed community diversity between PB and CONV tillage during the 2008/09 season in Wards 12 and 14, there were differences in the density of some weed species. The weed *A. hispidum* occurred in greater density in PB3- than in the other tillage systems after harvesting (Table 5.5). This weed is difficult to control as it produces multiple generations within one season (Chivinge *et al*., 1988). Since none of the PB3- farmers removed weeds at harvesting (Fig. 5.1), the increase in density of *A. hispidum* after harvesting may lead to high weed infestations in the future due to increased seed bank return. The seeds of *A. hispidum* can persist in the soil for more than 12 years (Schwerzel & Mabasa,

1986) so potentially any additional seed input can exacerbate problems in controlling this weed. Farmers in both Wards 12 and 14 performed the last hoe weeding in CF fields between late February and mid-March 2009 and this provided time for late season weeds such as *A. hispidum* to reach reproductive maturity (Plate 5.4) and subsequently replenish the seed bank before the dry season weeding was done from July. Farmers in both Wards 12 and 14 performed the last hoe weeding in PB fields between late February and mid-March 2009 and this provided time for late season weeds such as *R. scabra* to reach reproductive maturity (Plate 5.4) and subsequently replenish the seed bank before the dry season weeding was done from July. There is, therefore, a need to emphasise late season weeding in PB as farmers only confined frequent weeding to early in the cropping season. However, there is likely to be labour bottlenecks for weeding the early planted PB fields and harvesting late planted crops before livestock are set into the field.

Minimum tillage fields were, however, associated with significantly reduced density of *C. dactylon* with the effect significant ($P < 0.05$) at 7, 11 and 19 WAP (Table 5.5) relative to CONV tillage fields that had at least double the density of *C. dactylon* found in PB fields. This might be due to the smallholder farmer practices of ploughing followed by harrowing which generally propagated *C. dactylon* in fields as reported by Mabasa *et al*. (1995). The encroachment by *C. dactylon* into MT fields reported by Vogel (1994) and Makanganise *et al*. (2001) was not observed in PB fields monitored in Wards 12 and 14.

Table 5.5 Weed seedling density (m^{-2}) under maize of *A. hispidium* and *C. dactylon* under different tillage systems during different sampling periods in 2008/09 season in Wards 12 and 14 in Masvingo District

Tillage system	Weed density m^{-2} at WAP							
	A. hispidum				*C. dactylon*			
	7	11	19	Total	7	11	19	Total
CONV	3.2	1.2	1.2	4.6	1.3	1.2	1.1	1.8
PB3-	2.7	2.9	2.8	10.3	0.4	0.3	0.2	0.9
PB3+	2.1	1.0	1.2	5.1	0.2	0.2	0.2	0.3
LSD $_{(0.05)}$	ns	ns	1.47	ns	0.72	0.66	0.47	0.92

. Log (x + 1) transformed data presented *Abbreviations:* WAP – weeks after planting; CONV, mouldboard plough; PB 3-, 2 or 3 years under PB; PB 3+, > 3 years under PB; LSD - least significant difference; ns - not significantly different.

Plate 5.4 Harvested but un-weeded PB field in fifth year next to yet to be harvested conventional tillage maize crop in April 2009 in Ward 12, Masvingo District. *Abbreviations:* PB – planting basin

5.3.3.2.3 Influence of cultural practices on weeds under PB tillage

Total weed density during the 2008/09 season was between 200 and 600 weeds m^{-2} in most CONV and PB fields (Fig. 5.4). However, a few PB fields had a density of over 1 000 weeds m^{-2} which probably implied that factors other than tillage may have accounted for the high weed density in these fields. The differences in weed densities were reflected in time required for hoe weeding which ranged from 30 hours ha^{-1} to 420 hours ha^{-1} per weeding operation. Farmers identified the level of weed infestation and type of weeds as the main reasons for a lengthy hoe weeding operation. The three fields with the highest cumulative weed density (Fig. 5.4) also recorded the highest weed density at 3 WAP. The high weed infestations in these three PB fields were explained by the fact that at the time of the second weed count none of the three fields had yet received the second weeding in contrast to the other PB fields. The field with the fourth highest weed density recorded the highest weed density at seed bank sampling at which time the field had not yet been weeded. The differences in these outlier fields compared to other fields without early weeding it was highly probable that PB fields had higher weed density than CONV tillage fields early in the season as was observed at Matopos Research Station (Chapter 3).

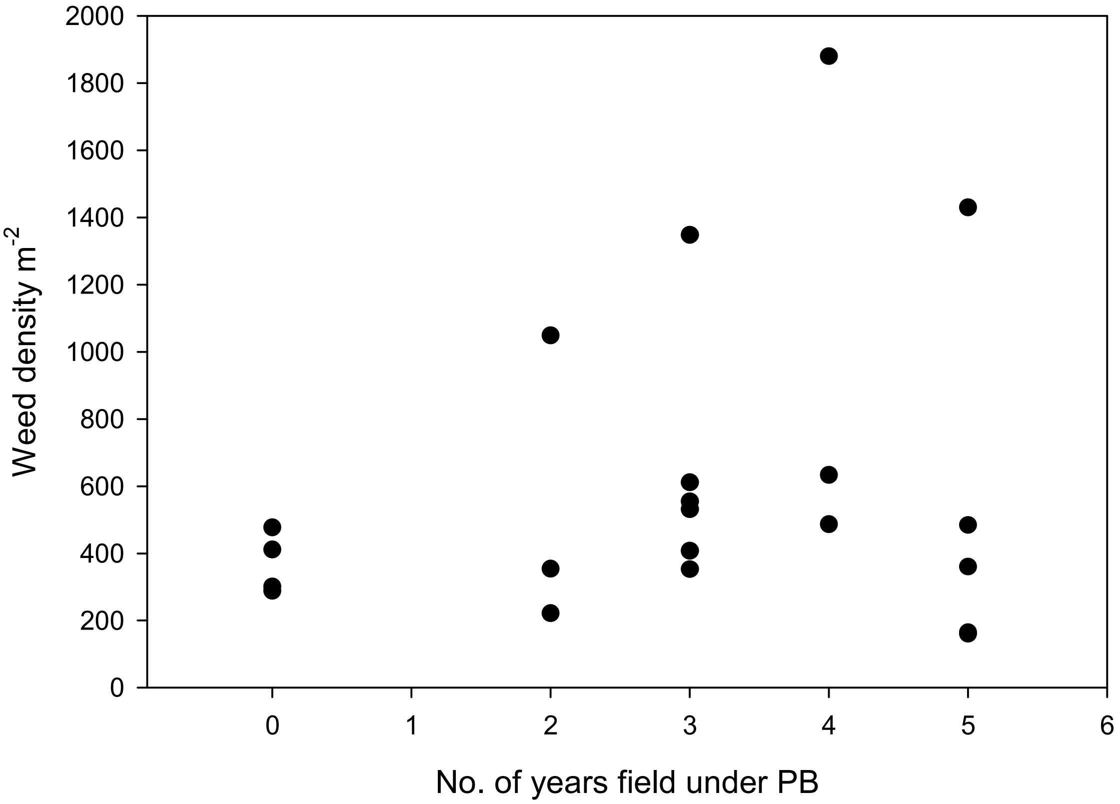

Fig. 5.4. A scatter-plot of the distribution of cumulative weed density (m^{-2}) in maize fields that had been under PB for different years in Wards 12 and 14 of Masvingo District during 2008/09 season. O (zero) years represents CONV tillage. *Abbreviation*: PB – planting basin ; CONV tillage - conventional mouldboard plough

A comparison of weeds within the planting basins and the inter-row area in PB fields indicated that planting basins had higher ($P < 0.05$) weed density throughout the 2008/09 cropping season than the inter-row area (Table 5.6). Significantly higher densities of *A. hispidum*, *E. indica*, *I. plebia* and *R. scabra* were found within planting basins than in the inter-row area (Table 5.7). A number of factors could be responsible for the higher weed density in planting basin than the inter-row area. The area within the planting basin was disturbed to a greater depth than the inter-row area and during basin preparation seeds that were previously buried may have been exposed to conditions suitable for germination resulting in increased seed germination. Secondly in PB, both organic and inorganic fertilisers are precision applied within the planting basin (ZCATF,

2009) and over time an area of high fertility may have been created in planting basins compared to the inter-row area in farmers' fields. Addition of nutrients can increase the germination of some nitroliphic weed seeds and / or lead to increased weed growth due to improvement in fertility of nutrient poor soil (Major *et al*. 2005). However, no significant relationship was found between the applied amount of compound D, AN, total and available N at planting and weed density during the 2008/09 season in this study.

Apart from improving soil fertility, addition of organic fertiliser may have also introduced weed seeds into the planting basins. Poorly processed or composted manure can be a source of additional weed seeds that will emerge during the cropping season. The weed species *A. hispidum*, *E. indica* and *R. scabra* that were found in higher numbers in planting basins in this study (Table 5.7) were among weed species that were reported to be spread in manure by Munguri *et al*. (1995) and Rupende *et al*. (1998). This together with the presence only in the PB seed bank of species such *Amaranthus hybridus* and *Corchorus tridens* that are associated with manure use (Table 5.2) suggested that the frequent use of manure in PBmay be contributing to increased weed infestations inPB. Since information on the amounts of manure applied during the 2008/09 season was not available for most farmers, the relationship between frequency of manure use in the past four seasons (2005/06 to 2008/09 seasons) and weed density during the 2008/09 season was investigated. This revealed a weak ($R^2 = 0.38$) but significant ($P < 0.05$) relationship ($y = 0.003x^2 - 0.22x + 13.11$) between weed density at 3 WAP and frequency of manure use that suggested that the annual application of manure in PB may have been associated with an increase in weed density. Although the planting basin covered less than 20% of PB fields, introduction of new seeds through manure use could have led to increased weed infestations with time in PB when some of weeds escaped control and set seed that was later dispersed to the rest of the PB field. In addition the high soil moisture content reported in PB may have resulted in more vigorous weed plants within basins that without control added to the seed bank.

An implication of the high weed density within the planting basin was that of increased interference as the majority of weeds were in close proximity to the two maize plants grown per planting basin. Rambakudzibga *et al*. (2002) reported that maize grain yield was significantly lower with E. *indica* within 20 cm of maize row than with double the *E. indica* density spaced 40 cm away from maize row. The weed species *A. hispidum*, *E. indica*, *I. plebia* and *R. scabra* thst had high density within planting basins were identified as aggressive weeds by smallholder farmers in Masvingo Province in a survey carried by Chivinge (1988). Thus, weeds within the planting basin were likely to be more competitive than those in the inter-row area. It is recommended that farmers with labour constraints must remove the weeds growing within the planting basins before the ones in the inter-row area to avert significant crop yield loss.

Table 5.6 Weed density within basin and in the inter-row area in maize grown under PB fields in Masvingo District in 2008/09

Sampled area	Weed density (m^{-2}) at sampling period Seed bank	3 WAP	7 WAP	11 WAP	19 WAP	Total[§]
In basin	13.8	22.6	15.9	14.4	11.8	40.7
Inter-row	7.2	12.0	7.5	7.8	7.0	20.9
LSD $_{(0.05)}$	5.87	6.55	5.14	3.90	2.48	8.18

[§] Total: cumulative of 3, 7, 11 and 19 WAP. Square-root (x + 0.5) data presented *Abbreviations:* WAP - weeks after planting; LSD - least significant different; ns - not significantly different

Table 5.7 Density of specific weeds[∞] within basin and in the inter-row area in maize grown under basin fields in Masvingo District in 2008/09

Sampled area	Weed density m^{-2} *A. hispidum*	*E. indica*	*H. mueesei*	*I. plebia*	*R. scabra*
In basin	12.0	5.2	6.6	12.6	18.5
Inter-row	6.9	2.	3.4	5.5	9.3
LSD $_{(0.05)}$	4.8	2.3	2.2	5.9	5.2

[∞] Weed species that showed significant differences; [§] Total: cumulative of 3, 7, 11 and 19 WAP. Square-root (x + 0.5) data presented *Abbreviations:* LSD - least significant different; ns - not significantly different

5.3.4 Maize grain yield

Planting basins produced double ($P < 0.01$) the maize grain yield obtained in CONV tillage with the highest mean maize grain yield obtained from PB3+ (mean: 2 856 kg ha^{-1}). Maize grain yield increased ($P < 0.001$) with the number of years a field had been under PB (Fig. 5) probably as a result of better crop management in soil fertility and weeding in CF. There was a positive ($R^2 = 0.38$; $P < 0.01$) correlation between frequency of manure use and maize grain yield that showed that fields that frequently received manure were associated with high maize grain yield. Mutiro & Murwira (2004 reported that manure increased maize yield in the second and third year of application. Planting basin fields were probably benefiting from the annual application of manure compared to CONV tillage where manure was applied after three or four seasons.

The importance of weeding early in the cropping season was demonstrated by the relationship between weed density at 3 WAP and maize grain yield (Fig. 5.6) that showed that high weed density at 3 WAP was associated with low maize grain yield. This period falls within the critical period of weed control for maize which is reported to be between 2 and 6 weeks after crop emergence (Zimdahl, 1999; Mashingaidze, 2004). Similar yield increases of above 100% have been reported before for CF relative to CONV tillage by Mazvimavi and Twomlow, (2009) and Marongwe *et al*. (2011) in semi-arid Zimbabwe. The three fields that had the highest cumulative weed density in Fig 5.4 are the same outliers in Fig. 5.6 where, despite the high weed infestations in these fields high maize yields were still obtained. The high weed infestations were a result of weed density recorded at 3 WAP before the fields were weeded. However, the fields were weeded soon after the weed counts and the third weeding was done 15 days later. This frequent weeding averted any significant yield loss in these fields. The subsequent removal of the weeds after the weed sampling was not taken into account in the regression analysis presented. The four sites with low weed densities at 3 WAP but low maize grain yield are CONV tillage fields where poor weed management and low use of fertilisers probably contributed to reduced maize grain yield compared to PB plots.

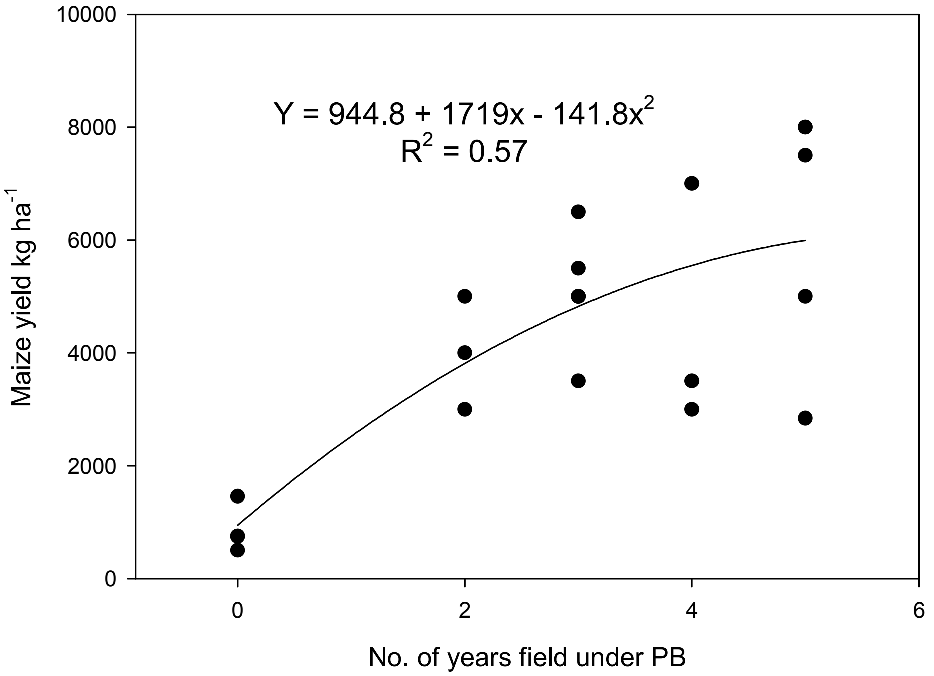

Fig. 5.5 Relationship between the number of years a field had been under PB and maize grain yield obtained from farms in Wards 12 and 14 of Masvingo District during the 2008/09 season. *Abbreviations*:PB– planting basin

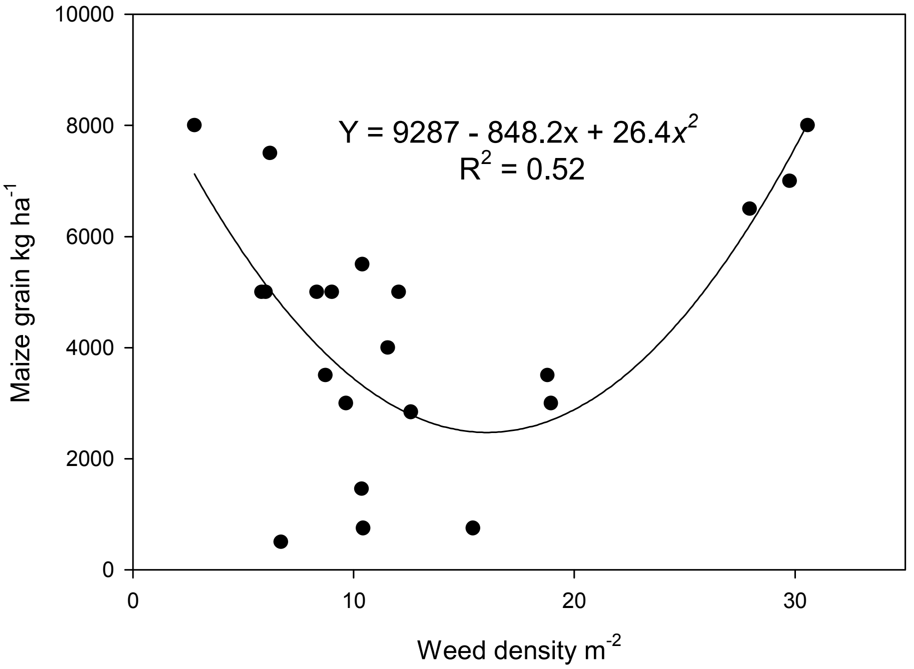

Fig. 5.6 Relationship between weed density at 3 weeks after planting and maize grain yield obtained from farms in Wards 12 and 14 of Masvingo District during the 2008/09 season

5.3.5 Farmer perceptions

5.3.5.1 Constraints to crop production

The same four factors were identified as the main constraints to crop production in Wards 12 and 14 by both CONV and PB farmers in November 2008 at the start of the study (Table 5.8). Most of the farmers in the CONV tillage group did not receive seeds and fertiliser from CARE and identified lack of inputs as the major constraint that often resulted in 50% or less of available land being cropped. Labour especially for weeding was the second most important constraint to CONV tillage farmers as most did not have implements such as cultivators to use for weeding. Farmers close to Lake Mutirikwi (Ward 14) identified hippos as a major constraint resulting in abandonment of some outer fields. The ranking of constraints in PB was low rainfall > input availability > labour > pests. The area under PB was equivalent to the inputs most farmers received from CARE International. When CONV tillage farmers were asked why they had not adopted CF, they cited the unavailability of fertiliser as the main reason. Most farmers perceive that without fertilisers there would be limited yield benefits to PB. Under the low areas committed to PB weeds could be managed with available family labour. These findings are in contrast to Marongwe *et al*. (2011) who observed that the high labour requirement, especially for weeding, was the main constraint under PB on most smallholder farms in Zimbabwe. Although not the most important constraint, labour availability was identified as a constraint suggesting that even if more inputs became available for use under PB, labour requirements would ultimately limit the area under PB. There is, therefore, a need to address both the issue of input availability and alternative weed control strategies to reduce the labour required for land preparation and weeding under PB. This would result in an increase in the area under smallholder PB and given the higher yields reported under PB, is likely ensure food security for most smallholder households.

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

Rank	Conventional tillage farmers	Planting basin
1	Lack of inputs.	Low rainfall.
2	Labour especially for weeding.	Input availability.
3	Pests such as hippos, cut worms.	Labour for digging basins, weeding and collecting forest litter.
4	Rainfall availability.	Pests such as termites, hippos, baboons.

5.3.5.2 Important weeds

The ranking of the important weed by CONV tillage farmers (Table 5.9) was in agreement with results from the field (Table 5.4). However, in PB only 3 of the weeds ranked as the most abundant by farmers were also identified as the most important weed species in monitored fields. Conservation farmers ranked *C. dactylon* as the second most abundant species in their fields (Table 5.9) although field studies had revealed the species to be less important in PB compared to CONV tillage. The low weed sampling intensity (2 quadrats per field) used in this study may be the reason for the difference in the ranking of *C. dactylon* from field monitoring and by farmers using pairwise ranking. The weed usually occurs in patches which were probably missed in some fields due to inadequate sampling.

Based on farmer observations, there appeared to be no marked shift in weed species in fields where CONV tillage was replaced by PB as the same weed species were identified as the most abundant in both systems. This agrees with results from the observational field study done during the 2008/09 season. The farmers were aware of the biological adaptations of the weed species and the limitations in their current weeding methods that allowed these weed species to persist in large numbers in their fields (Table 5.9).

The weed *C. dactylon* was identified as the most problematic weed in both CONV tillage and PB fields (Table 5.10) probably because of the difficulties faced by farmers in effectively controlling it using hoe weeding. The species *C. dactylon, R. scabra* and *A. hispidum* that were identified by farmers as difficult to control and problematic were among the most important weed species in fields during the 2008/09 season. Although the density of *L. martinicensis* was high in PB the weed was not identified as a problematic weed by farmers. However, not all the 20 weed species were undesirable as over 70% of identified weeds were reported to be beneficial to farmers. Among the benefits was use of species such as *Amaranthus* species, *B. pilosa*, *C. monophylla* and *C. tridens* as relish. The tubers of *C. esculentus* were also reported to be consumed by farmers. Some weeds were reported to have medicinal properties with *A. hispidum* and *O. latifolia* used to treat sores and *B. pilosa* identified as a traditional asthma treatment. The grass weed *E. indica* was used to make compost by farmers. Some weeds provided food for different types of livestock found on the farm. The species *L. martinicensis*, *I. plebia* and *C. benghalensis* were fed to rabbits and pigs while *R .scabra* and *Digitaria* spp. were fed to livestock including cattle. Some farmers reported not weeding fields after harvesting so that their livestock could graze on the weeds during the dry season. Since farmers often left out some of these beneficial weed species during hoe weeding, the use of herbicides such as glyphosate that indiscriminately kill all weeds may not be suitable under smallholder conditions. This may explain the observation made by Baudron *et al*. (2007) that some smallholder farmers are reluctant to use herbicides.

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

Weed	CONV rank	PB rank	Reasons given for ranking by farmers
C. dactylon	1	2	1. It is found in all crops and all types of fields. 2. Weed spreads during weeding and grows more vigorously than before. 3. It is not easily controlled by hoe weeding. 4. Plant has deep roots which help in spreading it so difficult to kill. 5. It regenerates easily in wet soil.
R. scabra	2	1	1. Weed produces a high number of seed. 2. Species has early vigorous growth and found in large numbers. 3. It is difficult to kill when weeding and re-grows if it rains. 4. Seed dispersed by wind and water.
A .hispidum	3	-	1. It has high seed production. 2. Weed can re-grow if it rains soon after weeding.
Digitaria spp.	4	4	1. It spreads rapidly through the field. 2. It can re-grow if it rains after weeding. 3. It has high seed production. 4. Difficult to weed due to dense root system.
H. mueesei	5	5	1. It has a high seed production. 2. It has a dense root system which makes it difficult to uproot and weed.
L. martinicensis	-	3	1. Weed has high seed productivity. 2. Seed dispersed by run-off water and wind. 3. It is also spread by livestock.

Abbreviations: CONV - conventional moudboard plough; PB – planting basin

Table 5.10 The five most difficult to control weeds ranked by farmers in Wards 12 and 14 of Masvingo District in August 2009

Number	Weed	Reasons given for ranking by farmers
1	*C. dactylon*	1. It spreads during weeding process 2. It has a deep root so difficult to kill. 3. If soil is wet, it re-grows soon after weeding. 4. It multiplies by both seed, stolons and tubers
1	*E indica*	It has a dense root system so difficult to uproot.
3	*R. scabra*	1. It re-grows if it rains soon after weeding. 2. Weed has vigorous growth
3	*Digitaria* spp.	1. It spreads using stolons. 2. It grows rapidly.
5	*H. meeusei*	1. It has a deep root system so difficult to uproot. 2. It can re-grow if it rains after weeding. 3. Difficult to weed due to dense weed system.

5.4. Conclusion

The minimum tillage system of planting basins was the only CF practice adopted by farmers in Ward 12 and 14 of Masvingo district. There was no evidence of a decline in weed density in both the soil seed bank and above-ground weed flora with years the field had been under PB in Wards 12 and 14 of Masvingo District. Although weed density did not significantly ($P > 0.05$) differ between PB and CONV tillage throughout the 2008/09 cropping season, the earlier hoe weeding carried out in PB compared to CONV tillage suggested higher early season weed growth in PB relative to CONV tillage. The first hoe weeding was done at least 15 days earlier ($P < 0.05$) in PB than in CONV tillage. In addition, three post-planting weedings were done in PB compared to only two in CONV tillage. This increased weeding effort may be one of the reasons PB was practiced on less than 50% of the cropped area on the majority of farms despite the higher crop yields obtained in PB. At least double the maize grain was obtained from PB compared to CONV tillage (mean: 1 052 kg ha^{-1}) with yield observed to increase with number of years the field had been under PB. Improvements in soil fertility and weed management likely contributed to the increased maize grain yield under PB. The decrease in maize grain yield with increased weed density at 3 WAP highlighted the importance of early season weed control. However, farmers did not identify labour for weeding as the most important constraint in PB probably because farmers were using PB on small acreages that were equivalalent to the seed and fertilisers provided by NGOs. There is need to determine whether weed density in PB was higher than in CONV by carrying out weed assessment before farmers weed fields over a number of seasons. Further research needs to be done on the economic feasibility of herbicide use to reduce the weeding burden early in the cropping season. There is also a need to determine weed seed viability in manure as the annual application of manure in PB may have introduced additional weed seeds and new weed species in some PB fields.