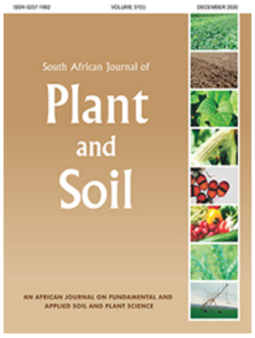

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Intra-seasonal activity of ground dwelling spiders following six years of tillage, fertiliser and weeding treatments in an agricultural field in northern Zimbabwe

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Spiders are important biological control agents whose activity and diversity can be negatively affected by agricultural practices. A study was conducted at Chinhoyi University of Technology experimental farm, northern Zimbabwe, to determine the impact of tillage, fertiliser application and weeding regimes on ground-dwelling spiders across three maize crop growth stages (early vegetative: V3; late vegetative: V6; and intermediate reproductive: R2). Lycosidae were the most abundant spider family (85.7%) while Salticidae were least abundant (0.8%). The spiders belonged to two functional groups, ground and plant wanderers with the former constituting 94.9% of pitfall catches. Spiders were most abundant during V3, followed by R2 and V6 maize growth stages. Spider community diversity was also greatest during the V3 (H' = 0.45) and least during the V6 stage (H' = 0.12). During the V3 and R2 stages, ground dwelling spider abundance was higher in the two reduced tillage systems than under conventional tillage. Based on the study findings, it can be concluded that reduced tillage is useful in increasing ground-dwelling spider community abundance and diversity during the V3 and R2 maize growth stages.

Keywords: biological control, conservation agriculture, predator, spider functional groups

Introduction

Soil is one of the most diverse habitats on earth, also containing some of the most diverse assemblages of living organisms, including macro-arthropods, nematodes, earthworms and microorganisms such as fungi and bacteria (Briones 2014). Spiders are among the predominant surface dwelling macro-arthropods that serve as biological pest control agents due to their predatory behaviour. Having insects and collembolans as their major prey, spiders are reported to kill close to one billion tonnes of prey every year, globally (Nyffeler and Birkhofer 2017). They occupy different spatial niches including soil, litter and plant canopies. Having an obligate carnivorous feeding habit, spiders employ different hunting and foraging strategies including ambushing, physical hunting as well as the use of webs to catch their prey (Whitcomb 1974; Japyassú and Caires 2008; Michalko and Pekár 2016; Nyffeler et al. 2016). Based on their foraging behaviour, spiders can be placed into three distinct functional groups (Uetz et al. 1999). First, ground wanderers include spider groups that move around on the soil surface in search of their prey, e.g. Lycosidae, Gnaphosidae and Ctenidae. Second, plant wanderers move up and down plant canopies and in doing so they catch their prey. Examples include Salticidae and Thomisidae. Third, web builders construct webs in the aerial space to trap and catch their prey. Ground wanderers are important predators of soil pests while plant wanderers and web builders are natural enemies of aerial pests (Marc et al. 1999).

Agricultural management activities such as tillage, soil fertility amendment and weed management have been shown to influence the local habitat, soil-inhabiting organisms, and relationships between organisms (Shennan 2008; Plaas et al. 2019). With regard to soil tillage, its intensity, method, frequency and timing have been shown to impact upon predatory arthropods, particularly those that are associated with the soil (Kromp 1999; Holland 2004; Pretorius et al. 2018). Conventional tillage (CT), a common practice particularly among smallholder farmers in sub-Saharan Africa, involves soil inversion using a mouldboard or disc plough as primary tillage followed by secondary tillage usually using a disc harrow (Giller et al. 2009). This practice is destructive to the physical, chemical and biological structure of the soil. To achieve the goal of safe productivity, protection of natural resources is needed through practices such as reduction or exclusion of soil inversion tillage. The majority of soil-dwelling biota require a stable soil mass for sustained breeding, refuge and survival. The general pattern is that both the abundance and diversity of the soil fauna tend to increase with decreasing tillage intensity (Kromp 1999; Soane et al. 2012). Reduced tillage systems, such as conservation agriculture (CA) create a more stable environment, encouraging the development of more diverse species including decomposer communities that are important in encouraging faster decomposition of soil organic material (Soane et al. 2012). Moreover, CA has been shown to have profound positive effects on spider communities in both temperate and tropical environments, and this may be important in biological control of insect pests (Ayuke et al. 2019;

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Mashavakure et al. 2019). Conservation agriculture involves the simultaneous application of three key principles: (1) no or minimum mechanical soil disturbance, (2) maintenance of a permanent or semi-permanent plant residue cover on the soil surface, and (3) species diversification through varied crop sequences and associations involving at least three different crops (Jat et al. 2012).

While CA has been shown to have positive effects on spiders regardless of their functional traits (Mashavakure et al. 2019), its influence on intra-seasonal population dynamics has received little attention. With regards to insect pests, their population densities usually fluctuate within each cropping season, reaching a peak during the most vulnerable crop growth stage. It is therefore desirable that peak spider abundances coincide with crop growth stages when pest populations are also expected to be at their peak so that the maximum benefits of biological control can be realised. In their study on soybean (*Glycine max* L.) in northern Zimbabwe, Mukobvu et al. (2019) found Lycosidae, Salticidae and total spider abundances to peak during the late vegetative and physiological maturity stages of the crop. In this study, Mukobvu et al. (2019) also observed that minimum tillage resulted in higher spider abundance relative to CT. The authors further noted that the vegetative growth stage was critical because most economically important insect pests of soyabean occur at this time, and therefore, the stage when it is important to protect the crop from pest damage.

Intra-seasonal changes in spider abundance are expected to respond to changes in biotic and abiotic variables such as temperature, moisture, plant phenology and architecture as well as prey availability, e.g., herbivorous arthropods (Welch et al. 2011). The retention of plant residues on the soil surface, as practised in CA, moderates soil temperature and moisture, resulting in concomitant positive effects on vegetation and soil dwelling biota (Ghosh et al. 2015; Shen et al. 2018). Apart from its direct effects on soil structure, tillage can influence the abundance of invertebrates by physically disturbing habitats and altering availability of food sources (Stinner and House 1990). Additionally, tillage may affect invertebrates living on the surface by influencing litter layer build-up and availability of shelter. Whereas weeds compete with crop species, they can play an important role in increasing vegetation diversity, a feature that is normally lacking in cropping systems (Jastrzębska et al. 2013; Gaba et al. 2016). Weed vegetation provides beneficial services such as providing habitats for predators of insect pests and food resources for herbivorous prey. Weed management in cropping systems alters vegetation diversity and biomass production, both of which are important drivers of arthropod community structure. Another factor is mineral fertiliser application, which has been used to maintain soil fertility and increase crop production for many years (Murugappan et al. 2007). Inorganic fertilizer application has indirect effects on the food web through increasing plant biomass production, which supports high numbers of insect pests as well as detritivorous arthropods, thus enhancing predator abundance (Siemann 1998). Globally, most farmers produce food under intensive farming systems which include high use of external inputs that have the potential to threaten global biodiversity, food security and human health. While the individual effects of cultural practices on spiders is well documented, their interactive role in influencing temporal changes in spider populations during a single crop growth cycle is not fully understood. Interestingly, these cultural practices are employed simultaneously in most cropping systems. In this study, it was hypothesised that CA, fertiliser application and low weeding intensity increase spider activity throughout the maize (*Zea mays* L.) crop growth cycle.

Materials and methods

Site description

The study site was located in a semi-humid region at Chinhoyi University of Technology experimental farm (17°20′S; 30°14′E, altitude 1 140 m), Zimbabwe (Figure 1). Chinhoyi University of Technology experimental farm is about 110 km northwest of the capital, Harare. Annual total precipitation for this region ranges from 800 to 1 000 mm, with mean temperatures of 15 and 27°C in winter and summer, respectively. The rainfall pattern is unimodal, occurring between October and May each year. Soils are Chromic Luvisol (WRB 2015) with a pH (1M $CaCl_2$) of 6.0, and high silt and fine sand content making it prone to surface capping (Kodzwa et al. 2020).

Experimental design and treatments

A long-term experiment was established at the site in December 2012 with tillage, fertiliser and hand weeding treatments being repeatedly applied on the same plots during successive summer cropping seasons. The experiment followed a split-split plot arrangement in a randomised complete block design with three replications. Three tillage systems (basin planting, rip lines and conventional tillage) constituted the main plot factor. Basin planting and rip lines represented reduced tillage (RT). Planting basins were prepared following Mazvimavi and Twomlow (2009) making sure that each basin measured 15 × 15 × 15 cm, length, width and depth respectively. Rip lines were prepared using a tractor mounted ripper to a depth of approximately 15 cm. For conventional tillage (CT), primary tillage was done using a tractor mounted disc plough to a depth of 20-30 cm soon after harvesting. This was followed by secondary tillage using a disc harrow to achieve a fine tilth before planting. All crop residues were removed immediately after harvesting in CT plots to emulate traditional farmer practice in sub-Saharan Africa. The crop residues were retained on the surface in rip line and planting basin treated plots to achieve at least 30% soil cover. Four fertiliser rates formed the subplot treatments: (1) zero fertiliser application (NF), (2) micro dosing (LF): 100 g of manure per plant position + 80 kg ha^{-1} compound fertilizer (8 N: 14 P_2O_5: 7 K_2O) + 80 kg ha^{-1} ammonium nitrate (34.5% N) (total rate: 35.2 kg ha^{-1} N: 12.2 kg ha^{-1} P_2O_5: 6.6 kg ha^{-1} K_2O), (2) medium fertiliser (MF): 100 kg ha^{-1} compound fertilizer (8 N: 14 P_2O_5: 7 K_2O) + 100 kg ha^{-1} ammonium nitrate (34.5% N) (total rate: 41.5 kg ha^{-1} N: 14 kg ha^{-1} P_2O_5: 7 kg ha^{-1} K2O) and (4) high fertiliser (HF): 200 kg ha^{-1} of a compound fertiliser (8 N: 14 P_2O_5: 7 K_2O) + 200 kg ha^{-1} ammonium nitrate (34.5% N) (total

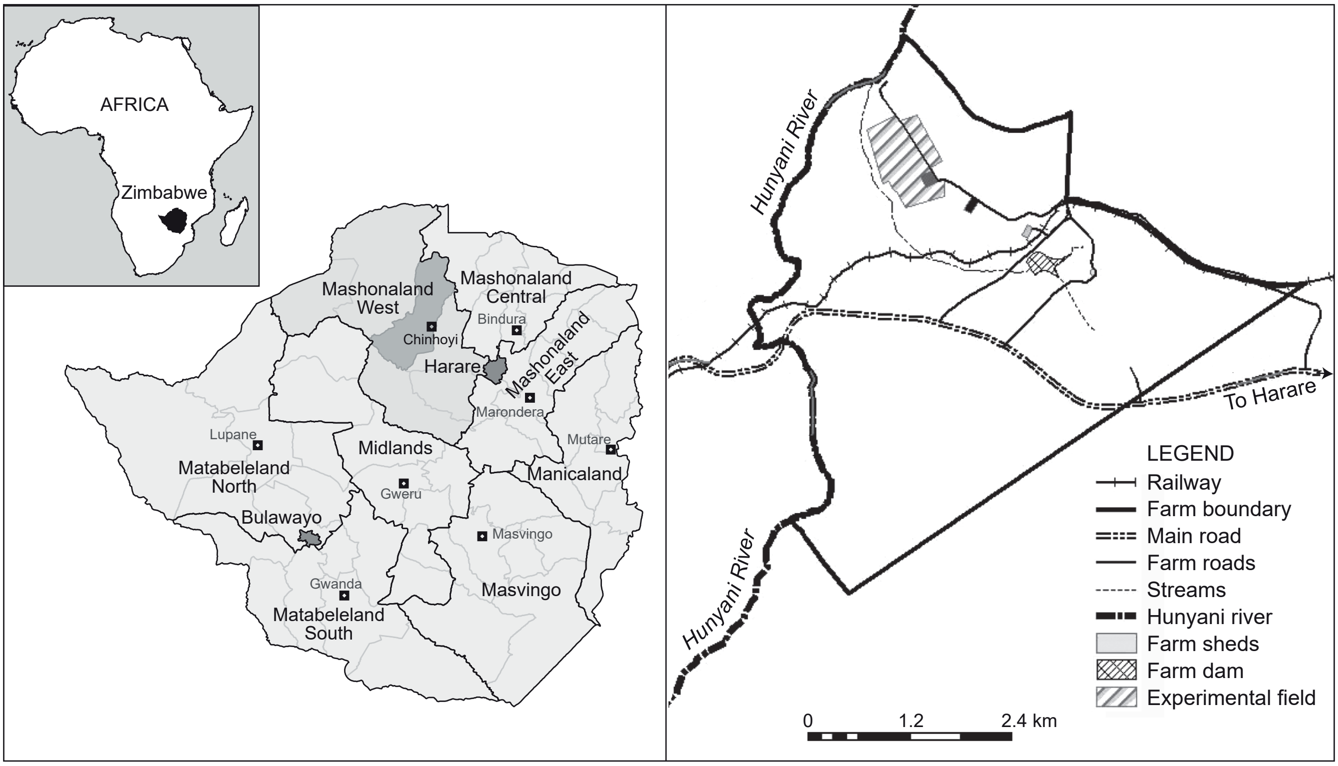

Figure 1: Study site location at Chinhoyi University of Technology experimental farm, Zimbabwe

rate: 83 kg ha^{-1} N: 28 kg ha^{-1} P_2O_5: 14 kg ha^{-1} K_2O). The sub-subplot factor was weeding intensity with weeding twice (weeding at two and four weeks after crop emergence (WACE)), weeding four times (weeding at two, four, six and eight WACE) and clean weeding in which continuous hand weeding was done to ensure that no weed growth occurred. Maize was planted using a plant spacing of 90 cm between rows and 50 cm between plants in a row, with two plants per position to achieve a plant population of 44 444 plants ha^{-1}.

Data collection

Spider sampling was conducted between January and April 2019, exactly six years after successive application of treatments on the same plots. Sampling was done at three maize growth stages: (1) vegetative stage 3 (V3) at 15-30 days after maize crop emergence, (2) vegetative 6 (V6), when the maize crop started to form silk, and (3) reproduction stage 2 (R2), when the maize crop had milky kernels. The spiders were sampled using non-baited pitfall traps, made of plastic jars with a diameter of 13 cm and volume of 1 000 cm^3. Traps were placed into the ground with the brims level with the ground surface. Each trap was half filled with a 20% alcohol solution to collect and preserve spider specimens. Two trap positions were randomly selected in each sub-subplot, placed at least 2 m apart. During each sampling period, traps were left in the field for seven (7) days, and spiders were collected in vials containing 70% alcohol on the third and seventh days. After the seven (7) day sampling period, the traps were not set for 14 days by closing them with a plastic sheet to avoid continuous capturing of arthropods. Spiders were counted and identified to family level in the laboratory according to Dippenaar-Schoeman and Jocque (1997) and then to functional groups according to Uetz et al. (1999).

Data analysis

The Shannon-Weaver (H') diversity index, species evenness and richness for the spider community were estimated for each experimental plot using a Paleontological Statistical (PAST) package (Hammer et al. 2001). Spider abundance data were transformed ($\sqrt{(x+2.5)}$)to normalise data distribution and homogeneity of variances. However, spider diversity data did not require transformation. To determine treatments effects on spider abundance and diversity across the three maize growth stages, an analysis of variance (ANOVA) was performed on the data using GenStat software package 14th edition (VSN-International 2011). The general ANOVA model was used with tillage system, fertiliser application rate, weeding intensity and crop growth stage and all their interactions as predictor variables:

treatment structure = tillage system × fertiliser application rate × weeding intensity × crop growth stage

block structure = block/tillage/fertiliser application rate/ weeding intensity)

while spider abundance and diversity were the response variables. Where significant differences were detected, mean separation was done using standard error of difference (±SED).

Results

Spider community and diversity across maize growth stages

A total of 1 038 individual spiders from six families (Lycosidae: 85.7%, Gnaphosidae: 6.6%, Oxyopidae: 2.9%, Philodromidae: 2.6%, Thomisidae: 1.4% and Salticidae: 0.8%) were collected during the study. These belonged to two functional groups, i.e. ground and plant wanderers, with relative abundances of 94.9% and 5.1%, respectively.

Except for Salticidae and Philodromidae, abundances of spider families and functional groups varied significantly ($p < 0.05$) across maize growth stages (Table 1). Overall, spiders were more abundant during the V3 stage relative to the V6 and R2 stages (Table 2). For Lycosidae and total spider abundance, these variations were confounded by significant interactions of tillage and crop growth stage (see subsection 3.2). Abundances of the functional group ground wanderers were just more than three times higher during the V3 stage compared to the V6 and R2 stages. Meanwhile, abundance of the functional group plant wanderers was highest during the V3 stage with 9.2 individual per pitfall trap, followed by the R2 stage (3.4 individuals per pitfall trap) and was least during the V6 stage (1.7 individuals per pitfall trap). All the three spider diversity parameters (richness, evenness and Shannon-Weaver diversity index) showed significant variations ($p < 0.05$) across maize crop growth stages (Table 1). A

Table 1: Results of general analysis of variance showing the main and interactive effects of tillage system, fertiliser application rate, weeding intensity and crop growth stage on the abundance of six families, two functional groups and diversity of spiders collected from a maize field during the 2018/2019 cropping season, Chinhoyi University of Technology experimental farm, Zimbabwe.

Response variable	*T*	*F*	*W*	*S*	*T* × *F*	*T* × *W*	*F* × *W*	*T* × *S*	*F* × *S*	*W* × *S*	*T* × *F* × *W*	*T* × *F* × *S*	*T* × *W* × *S*	F × W × S	T × F × W × S
Families															
Lycosidae	**	ns	ns	***	ns	ns	ns	*	ns	ns	ns	ns	*	ns	ns
Thomisidae	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Gnaphosidae	ns	ns	ns	***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Oxyopidae	ns	ns	ns	***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Philodromidae	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Salticidae	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Total	**	ns	ns	***	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
Functional groups															
Ground wanderers	***	ns	ns	***	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
Plant wanderers	ns	ns	ns	ns	ns	ns	ns	***	ns	ns	ns	ns	ns	ns	ns
Diversity															
Richness	ns	ns	ns	***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Evenness	*	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
Shannon-Weaver	ns	ns	ns	***	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

T = tillage system, *F* = fertiliser application rate, *W* = weeding intensity, *S* = crop growth stage, ns = not significant at $p \leq 0.05$, *significant at $p \leq 0.05$, **significant at $p \leq 0.01$, and, ***significant at $p \leq 0.001$.

Table 2: Spider community abundance (square root (x+2.5) and mean (in parentheses)) and diversity across three maize growth stages between January and April 2019, Chinhoyi University of Technology experimental farm

Spider groups and diversity	Maize growth stages			SED	*p*-value
	V3	V6	R2		
Families					
Lycosidae	3.23 (7.92) ^{c}	2.03 (1.61) ^{a}	2.41 (3.29) ^{b}	0.02418	<0.001
Thomisidae	1.63 (0.14) ^{b}	1.59 (0.02) ^{a}	1.60 (0.05) ^{a}	0.01138	0.002
Gnaphosidae	1.82 (0.80) ^{b}	1.61 (0.09) ^{a}	1.62 (0.11) ^{a}	0.02418	<0.001
Oxyopidae	1.66 (0.27) ^{b}	1.61 (0.08) ^{a}	1.61 (0.08) ^{a}	0.01643	<0.001
Philodromidae	1.68 (0.32) ^{b}	1.59 (0.03) ^{a}	1.59 (0.04) ^{a}	0.01683	<0.001
Salticidae	1.60 (0.06)	1.60 (0.06)	1.58 (0.01)	0.00833	0.091
Total	3.49 (9.69) ^{c}	2.11 (1.94) ^{a}	2.50 (3.75) ^{a}	0.0806	<0.001
Functional groups					
Ground wanderers	3.42 (9.16) ^{c}	2.05 (1.72) ^{a}	2.44 (3.43) ^{b}	0.0805	<0.001
Plant wanderers	1.73 (0.47) ^{b}	1.63 (0.16) ^{a}	1.62 (0.14) ^{a}	0.02168	<0.001
Diversity					
Richness	2.19 ^{b}	0.96 ^{a}	1.13 ^{a}	0.1061	<0.001
Evenness	0.81 ^{b}	0.72 ^{a}	0.80 ^{ab}	0.0435	0.013
Shannon-Weaver	0.45 ^{c}	0.12 ^{a}	0.13 ^{b}	0.0378	<0.001

Different superscript letters within each row indicate significant difference ($p \leq 0.05$).

significantly higher ($p < 0.001$) Shannon-Weaver diversity index was observed during the V3 ($H' = 0.45$) compared to the R2 ($H' = 0.13$) and V6 ($H' = 0.12$) stages (Table 1). Spider community richness was also higher during the V3 (richness = 2.19) and lower during the V3 (richness = 0.96) and R2 stages (richness = 1.13). Again, the significant effect of crop growth stage on spider community evenness was cofounded by a significant effect ($p < 0.05$) of tillage × crop growth stage interaction (Table 1) as described in subsection 3.2.

Treatment effects on spider abundance and diversity

The effects of fertiliser application rate and weeding regime on spider abundance and diversity were not significant ($p > 0.05$, Table 1). With respect to tillage system, significant effects ($p < 0.05$) were observed on the functional group ground wanderers, the family Lycosidae and total spider abundances as well as family evenness. However, these significant effects of tillage were confounded by significant interactions of tillage and crop growth stage. Significant interaction ($p < 0.05$) of tillage × crop growth stage revealed that early in the season at the V3 stage and late in the season at the R2 stage of growth, basin planting and rip lines resulted in higher abundances of the functional group ground wanderer, family Lycosidae and total spider count relative to CT (Figures 2a-c). Meanwhile, at the intermediate V6 growth stage, the effects of tillage on spider abundance appeared to be slight, with rip lines recording the same as both basin planting and CT, while higher spider abundances were recorded in basin planting than CT. A significant three-way interaction ($p < 0.05$) of tillage, weeding intensity and crop growth stage was observed on abundance of the family Lycosidae. In particular, during the V3 stage, clean weeding under basin planting had higher Lycosidae abundance relative to weeding twice and four times while in CT, clean weeding resulted in reduced abundance of this family compared to weeding twice (Figure 3). The effects of weeding intensity on the family Lycosidae were not significant across tillage systems during the V6 stage. With regards to the R2 growth stage, Lycosidae abundance was lower in clean weeded plots than those that were weeded twice under rip lines. For spider diversity, tillage system had no effects on spider community evenness early in the season at the V3 crop growth stage (Figure 4). However, later during the V6 and R2 stages, the two RT systems had significantly higher ($p < 0.05$) spider family evenness (31.3–34.1% for the V6 and 40.7–55.3% during the R6 stage) relative to CT. All other interaction effects on spider abundance and diversity were not significant ($p > 0.05$).

Discussion

Lycosidae and the functional group ground wanderers were the most dominant groups of spiders in this present study. This corroborates previous studies that reported these groups to be among the predominant spiders in agroecosystems in Uruguay (Bao et al. 2018) and Pakistan (Butt and Sherawat 2012). However, it should be noted that the method used for trapping the spiders selectively catches ground dwelling arthropods. Ground-dwelling spiders, including Lycosidae, have been shown to reduce densities of armyworm (*Pseudaletia unipunctata* (Haworth)) larvae, some sucking pests (Delphacidae and Cicadellidae) and several lepidopteran insect pests (Maloney et al. 2003).

The study showed that ground dwelling spider abundance in maize agroecosystems follows a cyclical pattern, being most active and abundant during the V3 stage of maize growth. This is probably related to the emergence and growth patterns of different generations of spiders, which could also be linked to resurgence/recession cycles of herbivorous prey during the crop growth cycle. Interestingly, for some important maize pests such as fall armyworm (*Spodoptera frugiperda* J.E.Smith),

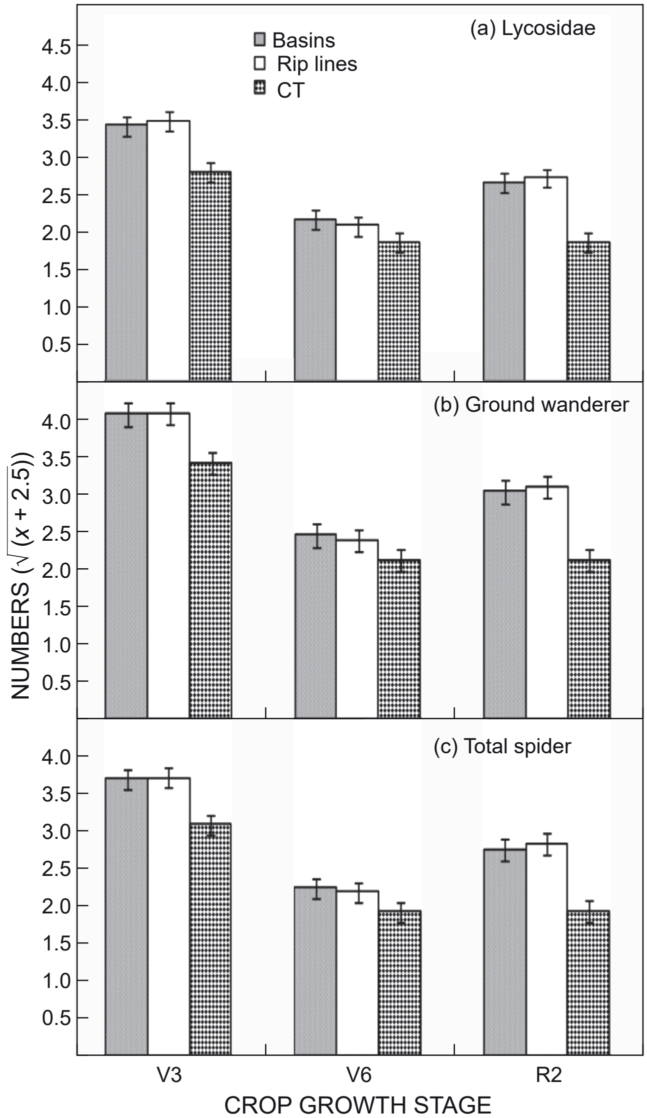

Figure 2: Tillage effects on Lycosidae (A), ground wanderer (B) and total spider (C) abundance across three maize growth stages between January and April 2019, Chinhoyi University of Technology experimental farm. Error bars are ±SED for the comparison of tillage system means within and across maize crop growth stages, CT = conventional tillage, Rip lines = rip line seeding, Basins = basin planting.

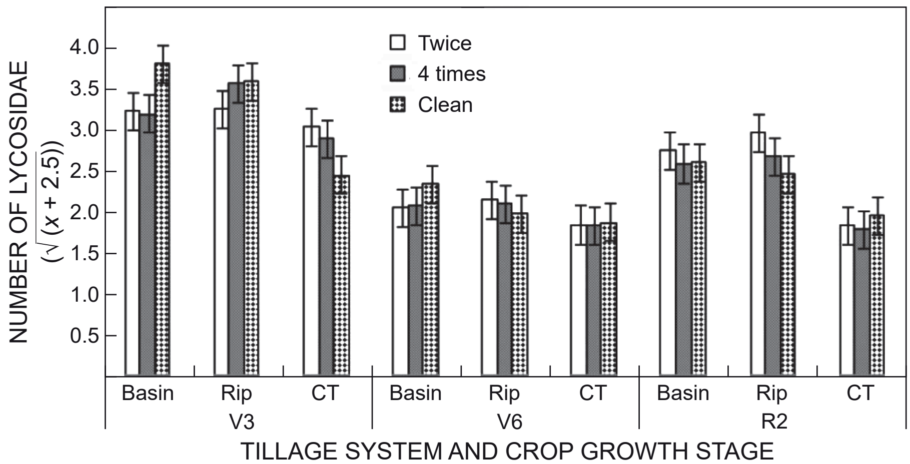

Figure 3: Effects of weeding on Lycosidae abundance across three tillage systems and three maize growth stages between January and April 2019, Chinhoyi University of Technology experimental farm. Error bars are ±SED for the comparison of weeding intensity and tillage system means within and across maize crop growth stages, CT = conventional tillage, Rip lines = rip line seeding, Basins = basin planting.

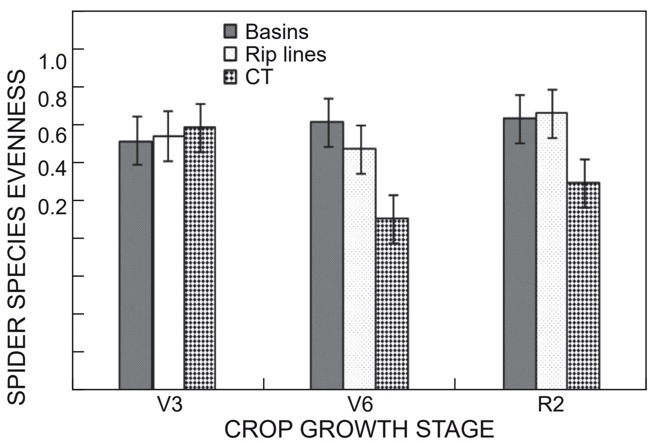

Figure 4: Tillage effects on spider community evenness across three maize growth stages between January and April 2019, Chinhoyi University of Technology experimental farm. Error bars are ±SED for the comparison of tillage system means within and across maize crop growth stages, CT = conventional tillage, Rip lines = rip line seeding, Basins = basin planting.

high larval densities have been reported during the V1-V3 stages (Murúa et al. 2006). The decline in spider numbers during the V6 stage may be attributed to reduced spider reproduction and growth during this maize growth cycle. A little later during the R2 stage, spider population showed a resurgence, probably signalling the emergence of a new generation of spiders during the same season. In a study of phenological changes of spider populations in alfalfa (*Medicago sativa* L.) in the United States of America, Welch et al. (2011) also found cyclical changes in spider population densities over the crop's production cycle. In fact, the findings of Welch et al. (2011) provide some evidence of synchrony between spider communities and their prey as peak abundances of the former were observed to coincide with critical phases of pest life cycles. It is therefore important to determine the cyclical patterns of major insect pests of the concerned crops, and in the case of our study, maize. This understanding will help in designing crop management systems that promote ground-dwelling spider abundance to peak at periods when insect pest densities are also at their highest.

Consistent with the recent studies on spiders and other biota in the same environment, the main effects of fertiliser and weeding on spider communities were not evident throughout the three maize growth stages (Mashavakure et al. 2018; 2019). The spider family Lycosidae exhibited a positive response to basin planting + clean weeding during the V3 stage and a negative response to CT + clean weeding and rip lines + clean weeding during the V3 and R2 stages, respectively. Since the basin planting system is presumed to contain higher resident populations of ground dwelling spiders at the onset of the cropping season, we infer that clean weeding helps to support growth of this initial population during the V3 stage. However, in CT where the soil surface is devoid of plant residues and initial spider population growth is perceived to depend on immigrating individuals, clean weeding keeps the soil bare and probably creates unfavourable conditions for ground dwelling spider communities.

The results of this present study showed that tillage effects on ground dwelling spider communities varied with crop growth stage, with more evident differences between the two RT systems and CT being observed during the V3 and R2 stages. The positive effects of RT during the two maize growth stages are possibly due to its indirect effects on the soil food web. Lack of soil disturbance and retention of surface residues in RT preserves habitats and moderates soil temperature, promoting macro-invertebrate populations. Increased density of ground dwelling spiders in RT relative to CT systems suggests that the former is important in enhancing spider populations that are resident rather than simply supporting those that immigrate into the system. However, the possibility of recruitment of spiders due to immigration was beyond the scope of this study but, as explained by Bianchi et al. (2017), cannot be ruled out. During the V3 and R2 stages, plant volatiles are probably high and more herbivorous prey visit the plants, creating favourable conditions for supporting higher populations of predatory faunae such as ground dwelling spiders. However, plant volatile production in the maize cropping system was not quantified in this study. The results of this study during the V6 and R2 stages were in agreement with those of Rendon et al. (2015) who found more even spider communities in complex than simple microhabitats in Australian cotton fields, and attributed this to the availability of overwintering substrates such as surface shelter.

Conclusion

Contrary to part of our hypotheses, the results of this present study clearly showed that fertiliser application and weeding intensity had no effect on spider communities throughout the three maize growth stages during which the study was conducted. Based on this evidence, it can be concluded that under the specific soil and environmental conditions, fertiliser application is not an important driver of ground dwelling spider communities in cropping systems. However, tillage system influenced spider communities particularly during the V3 and R2 maize growth stages; with higher spider abundance and evenness in the two RT systems than in CT. Increased spider abundance in maize cropping systems suggests that there is potential for farmers who practice RT to benefit from enhanced biological control due to increased spider activity. Future studies need to be focused on determining the interactive role of tillage system, fertiliser application and weeding regimes in regulating predator (spider)-prey interactions. More detailed studies are required to disentangle how spiders may ultimately influence pest complexes to the benefit of the crop.

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Declaration of interest

None.

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