Spiders (Araneae) in ground covers of pistachio orchards in South Africa

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As part of a larger study of arthropod diversity in pistachio orchards under IPM practices in South Africa, spiders (Araneae) living on ground cover plants were surveyed in two orchards (GVN 1 and GVN 19) at the Green Valley Nuts Estate and an orchard on the farm Remhoogte (REM) in the Prieska district, Northern Cape Province. Spiders were sampled from three different ground cover regimes in the orchards to determine their diversity, relative abundance and prey items of the numerically dominant species. Sampling was undertaken using a sweep net, with 200 sweeps per orchard per month, in July 2001, September 2001 to April 2002, and July 2002. In total, 1760 spiders representing 55 species were collected in the three orchards. Total spider numbers and diversity were highest at GVN 1 (n = 631, 40 spp.), followed by REM (n = 580, 36 spp.) and GVN 19 (n = 549, 35 spp.). Two species, *Peucetia viridis* (Blackwall) and *Heliophanus pistaciae* Wesolowska, dominated the spider fauna, accounting for 29.3 % and 23.4 % of the total, respectively. Plant composition and orchard age had a significant effect on the abundance of spiders, but a minimal influence on diversity. Predation events observed in the field for nine common spider species showed that they preyed on nine orders of insects, including various minor pests. The presence of spiders in the ground covers may play a role in suppressing populations of minor pests before they reach damaging levels in pistachio trees.

Key words: Araneae, ground covers, orchards, pistachio, predation, South Africa, spiders.

Ground covers comprise an important structural component in many orchard ecosystems, influencing natural enemy populations by increasing overall habitat complexity, providing alternative food for predators and serving as trap crops for herbivores with pest potential (Cortesero et al. 2000). All three factors can positively influence the survival and consequent pest management effects of natural enemy populations on pest organisms infesting the main crop.

Ground covers have been shown to increase the biological control effects on pest populations in orchards (Bugg & Waddington 1994; Wyss et al. 1995; Brown et al. 1997a). Like field margins, they also play an important role as overwintering sites for various natural enemies, ensuring the survival of the species until the next season when the agroecosystem can be recolonised (Dennis & Fry 1992; Dennis et al. 1994; Thomas & Marshall 1999). However, they need to be carefully selected as their composition may influence herbivore and predator populations in this vegetation, and in the tree canopies above (Bugg & Dutcher 1989; Bugg et al. 1991; Kaakeh & Dutcher 1993; Smith et al. 1994; Rieux et al. 1999). While cover crops and other floor vegetation can play a role in pest management, they cannot be relied upon to provide complete control of pests on the main crop (Costello & Daane 1998a).

Spiders are often the most abundant predators in various orchard ecosystems (Carroll 1980; Liao et al. 1984; Nyffeler & Benz 1987; Knight et al. 1997; Costello & Daane 1999), forming an essential part of the natural enemy complex. They can play an important role in the natural suppression of pest organisms, both on the main crop and in ground covers. Spiders have attributes related to pest mortality not often encountered in other natural enemy groups such as parasitoids, e.g. wasteful killing (unpalatable prey that are killed without feeding taking place), disturbance effects, positive responses to high prey densities, and the mortality of non-consumed pests in webs (Mansour et al. 1981; Samu & Bíró 1993; Riechert 1999; Sunderland 1999; Haddad et al. 2004). In addition, the different lifestyles or guilds of spiders ensure that a particular prey species may be captured by different methods (Marc & Canard 1997) and in various strata of the agroecosystem, a characteristic of ecosystem functioning known as resource-use complementarity (Wilby & Thomas 2002). All life-stages of spiders are predacious and can

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Table 1. Ground cover parameters in three pistachio orchards in the Prieska district, Northern Cape Province, at the start of the survey in July 2001.

Parameter	GVN 1	GVN 19	REM
Orchard age (years)	8	5	9
Orchard size (ha)	16	16	1.5
Ground cover characteristics	Mixed herbs, weeds and few grasses	Alternate rows of weeds and grasses	Mixed herbs and grasses, few weeds
Vegetation density	Moderately dense	Low	Dense
Dominant vegetation	Weeds	Equal distribution	Herbs

impact on pest populations. Many insect predators are only carnivorous in one life-stage (e.g. larval lacewings), and with their restricted movement, are more strongly influenced by prey density, patch restriction and cannibalism (Kindlmann & Dixon 1999). Furthermore, spiders are able to balloon to more suitable feeding sites if prey densities become too low. The most promising option for utilising the particular predatory nature of spiders for the biological control of pests is to increase their density in crops as close to the pest density as possible (Sunderland & Samu 2000). Smith et al. (1996) suggested that a high density of spiders in the ground cover layer often indicates that they are important predators in the orchard canopy.

Basic faunistic surveys are essential for determining agrobiont species in agroecosystems for further focused study, as these species are likely to have the greatest impact on pest populations by virtue of their abundance in the agroecosystems, and may also serve as bioindicators of pesticide residue effects in the ground covers of the crop. The aim of this study, the first of its kind in South Africa, was to determine the diversity and abundance of spider species in ground covers of pistachio (*Pistacia vera* L.) orchards, seasonal fluctuations in spider populations, the role of spiders as predators in this layer, and the effect of ground cover selection on arboreal populations.

Materials and methods

Study area and period

The study took place in pistachio orchards on two farms in the Prieska district in the Northern Cape Province, South Africa. Sampling was done in two orchards at Green Valley Nuts Estate (GVN, 29.35.18S, 22.56.68E), and an orchard at the farm Remhoogte (REM, 29.31.92S, 23.00.10E). All three orchards are managed according to IPM practices, and the only insecticides applied to the trees during the study period were endosulfan in December and parathion in April for the control of stink-bugs and other hemipterans. Benomyl was applied to control fungal pathogens in trees, and glyphosate was applied in the orchard rows to restrict weed encroachment on the pistachio trees. The natural vegetation in the area is classified as Orange River Nama Karoo (Hoffman 1996). Orchard parameters and ground cover composition of the three sampling sites are given in Table 1.

The spiders inhabiting ground covers in pistachio orchards were studied monthly from July 2001 to July 2002, but no sampling was undertaken in August 2001 and May and June 2002. The ground covers were mowed in each orchard during early September, early December and late March. Ground cover growth is most vigorous from early spring (September) to late autumn (May), and during this period the ground covers usually recovered within a few weeks following mowing.

Sampling methods

Spiders were collected using a sweep net with a diameter of 40 cm. Two transects of 100 sweeps, each comprising four 25-sweep sub-samples, were made in each orchard. Each sweep covered an arc of 1.0–1.5 m. A total of 200 sweeps were taken in each orchard per month. All material was sorted by hand on site and preserved in 70 % ethanol before proceeding with the next sub-sample. All spiders from each orchard were pooled to represent each months' sample. Material was subsequently sorted quantitatively and qualitatively, and identified, in the laboratory. Specimens were separated into guilds based on their foraging strategies. Wandering spiders were divided into plant wanderers (PW) and ground wanderers (GW), and web-building spiders into orb-web

builders (OWB), hackle-web builders (HWB), gum-foot web builders (GWB) and sheet-web builders (SWB).

Field observations of spider predation were made during sampling to determine the prey spectrum of the most common species. All prey capture events observed while sorting sweep samples were noted. Additional observations (1–2 hours per sample date) were made on weedy plants and in webs of web-building spiders to further determine the prey spectrum of spiders. Spiders and their prey items were identified in the field by the collector. Data were not processed quantitatively, but only in terms of the prey taxa captured by each spider.

Statistical analysis

Total spider numbers in the three orchards were subjected to chi-square analysis with Yate's correction, at a significance level of 95 %, to determine if ground cover structure and vegetation density have an effect on total spider abundance.

Species richness was calculated as the number of species captured in each orchard divided by the total species collected in the three orchards during the study. Sørensen's quotient of similarity was used to compare the similarity of the spider faunas of the three orchards. The formula used in this index is $QS = 2j/(a + b)$, where a and b are the number of species captured at two particular sites, and j the number of species common to both samples (Magurran 1988). A higher value (closer to 1) indicates that the faunas at the two sites are more similar, while a value closer to 0 indicates a more unique fauna in each habitat.

Results

Numbers, diversity and guilds

A total of 1760 spiders representing 55 species was collected in the three orchards in the ten months sampled (Table 2). Total spider abundance was highest in GVN 1 ($n = 631$), followed by REM ($n = 580$) and GVN 19 ($n = 549$). Total spider abundance was significantly higher ($P = 0.0184$, $\chi^2 = 5.56$, $P < 0.05$) in GVN 1 than in GVN 19, but numbers did not differ significantly between GVN 1 and REM, and REM and GVN 19.

Two species, the lynx spider *Peucetia viridis* (Blackwall) and jumping spider *Heliophanus pistaciae* Wesolowska, dominated the spider fauna. They accounted for 29.3 % and 23.4 % of the total number of spiders collected, respectively (Table 2). The only other species representing more than 5 % of the total were the crab spider *Thomisus stenningi* Pocock (6.5 %) and the jumping spider *Phlegra* sp. (5.8 %).

Species richness was highest in GVN 1 (0.727, 40 spp.), followed by GVN 19 (0.655, 36 spp.) and REM (0.636, 35 spp.) (Table 2). Sørensen's quotient values (Table 3) were highest (0.789) for the GVN 19-REM combination. This indicated that the two orchards with the most contrasting vegetation densities and compositions had the most similar fauna, and suggests that ground cover composition has a minimal influence on the diversity of spiders. When similarity was compared at guild level a similar pattern emerged. Sørensen's quotient values were only slightly higher for the plant-wandering guild in the GVN 1-GVN 19 combination (0.824) than for the GVN 19-REM combination (0.778). Ground wanderers and the various guilds of web-dwellers also displayed the most similar diversity between the orchards GVN 19 and REM. The reason for this pattern is not known, since the plant compositions of the two orchards are markedly different. Perhaps the presence of grasses in both orchards, while being scarce at GVN 1, could account for the greater similarity between GVN 19 and REM.

Sixteen of the 17 species that represented more than 1 % or more of the total fauna were found in all three orchards. Plant wanderers dominated the spider fauna dwelling on ground cover plants in terms of diversity and abundance (Fig. 1), comprising 76.7 % of the spiders and 38.2 % of the species present. Although ground wanderers were also diverse (29.1 % of all the species), they formed a comparatively small part of the total number collected (8.9 %). This pattern could be expected since sampling was conducted only by sweep-netting. Apart from the sheet-weavers, which comprised 7.1 % of the total (9.1 % of the species), most of the remaining guilds represented only a minor part of the spider population. These groups included hackle-web builders (3.0 %, and 1.8 % of the species), orb-weavers (2.7 %, and 9.1 % of the species) and gum-foot web builders (1.6 %, and 12.7 % of the species).

Seasonal abundance patterns

The seasonal fluctuation of spider populations in the three orchards followed a variable pattern (Fig. 2). Numbers were low in the winter, with a

Table 2. Species diversity and abundance of spiders collected from ground covers in three pistachio orchards in the Prieska district, Northern Cape Province, from July 2001 to July 2002.

Family/species	Guild[a]	GVN 1	GVN 19	REM	Total	% of total
ARANEIDAE						
Argiope australis (Walckenaer, 1805)	OWB		1		1	0.06
Neoscona blondeli (Simon, 1885)	OWB	10	6	10	26	1.47
Neoscona subfusca (C L Koch, 1837)	OWB	6	8	4	18	1.02
Prasonica sp.	OWB			2	2	0.11
CORINNIDAE						
Austrachelas sp.	GW	1			1	0.06
Castianeira sp. 1	GW	2			2	0.11
Castianeira sp. 2	GW		3		3	0.17
Trachelas pusillus Lessert, 1923	PW	1		1	2	0.11
DICTYNIDAE						
Archaeodictyna sp.	HWB	12	19	21	52	2.95
GNAPHOSIDAE						
Aneplasa nigra Tucker, 1923	GW	3	2	1	6	0.34
Camillina cordifera (Tullgren, 1910)	GW		4		4	0.23
Echemus sp.	GW	1			1	0.06
Micaria sp.	GW	2			2	0.11
Pterotricha auris (Tucker, 1923)	GW	2			2	0.11
Setaphis subtilis (Simon, 1897)	GW		1		1	0.06
LINYPHIIDAE						
Eperigone fradeorum (Berland, 1932)	SWB	2	7		9	0.51
Meioneta habra Locket, 1968	SWB	1	1	1	3	0.17
Meioneta sp.	SWB		1	4	5	0.28
Microlinyphia sterilis (Pavesi, 1883)	SWB	5		23	28	1.59
Ostearius melanopygius (O P-Cambridge, 1879)	SWB	51	17	12	80	4.55
LYCOSIDAE						
Pardosa crassipalpis Purcell, 1903	GW	2	6	12	20	1.14
Lycosinae sp.	GW			5	5	0.28
MITURGIDAE						
Cheiracanthium furculatum Karsch, 1879	PW	6	2	12	20	1.14
OXYOPIDAE						
Peucetia viridis (Blackwall, 1858)	PW	185	156	176	517	29.34
Oxyopes bothai Lessert, 1915	PW	8	18	1	27	1.53
Oxyopes hoggi Lessert, 1915	PW	1	1		2	0.11
PHILODROMIDAE						
Hirriusa arenacea (Lawrence, 1927)	GW	1			1	0.06
Philodromus sp.	PW	3	17	1	21	1.19
Suemus sp.	GW	6	19	32	57	3.24
Thanatus sp.	GW		1	6	7	0.40
PISAURIDAE						
Rothus vittatus Simon, 1898	PW			17	17	0.97
SALTICIDAE						
Heliophanus charlesi Wesolowska, 2003	PW	7	6	2	15	0.85
Heliophanus pistaciae Wesolowska, 2003	PW	168	52	191	411	23.35
Natta horizontalis Karsch, 1879	GW		1	1	2	0.11
Pellenes sp.	GW	1	1	1	3	0.17
Phlegra sp.	GW	55	42	5	102	5.80

Continued on p. 101

Table 2 (*continued*)

Family/species	Guild[a]	GVN 1	GVN 19	REM	Total	% of total
Pseudicius sp.	PW			1	1	0.06
Thyene aperta (Peckham & Peckham, 1903)	PW			1	1	0.06
Thyene inflata (Gerstaecker, 1873)	PW	4	2	1	7	1.40
THERIDIIDAE						
Enoplognatha sp.	GWB	1			1	0.06
Euryopis sp.	GWB	1	2	1	4	0.23
Latrodectus geometricus C L Koch, 1841	GWB		5	1	6	0.34
Latrodectus indistinctus O P-Cambridge, 1904	GWB	5			5	0.28
Theridion sp. 1	GWB	2	1	5	8	0.46
Theridion sp. 2	GWB		3		3	0.17
Tidarren sp.	GWB	1			1	0.06
THOMISIDAE						
Diaea puncta Karsch, 1884	PW		1	1	2	0.11
Heriaeus sp.	PW	9	23	2	34	1.93
Misumenops rubrodecoratus Millot, 1941	PW	47	12	15	74	4.21
Monaeses austrinus Simon, 1910	PW	3	8		11	0.63
Runcinia depressa Simon, 1906	PW	1			1	0.06
Thomisus machadoi Comellini, 1959	PW	1	8	1	10	0.57
Thomisus stenningi Pocock, 1900	PW	12	92	10	114	6.48
Xysticus sp.	GW	1			1	0.06
ULOBORIDAE						
Uloborus plumipes Lucas, 1846	OWB	1			1	0.06
TOTAL SPECIMENS		631	549	580	1760	100.00
TOTAL SPECIES		40	36	35	55	–
SPECIES RICHNESS		0.727	0.655	0.636	–	–

[a]GW = ground wanderers, GWB = gum-foot web builders, HWB = hackle-web builders, OWB = orb-web builders, PW = plant wanderers, SWB = sheet-web builders.

slight (GVN 19 and REM) and a sharp (GVN 1) increase in abundance in spring. This is a consequence of recovery of the ground cover growth due to increased rainfall in the spring and summer months, with an accompanying response by insect and spider populations. Numbers in all orchards peaked in summer (December–February), before decreasing markedly in March (probably due to further mechanical cutting of the ground cover and pistachio nut harvesting). Numbers recovered somewhat in April before decreasing to a low in July.

Seasonal abundance patterns of the two dominant species (Fig. 3) followed a similar pattern to that of the total spider catch, described above. This could be expected, as the two species together comprised nearly 53 % of the spiders collected in the ground covers. However, there was a noticeable difference in the population structure of the two species. Almost all *P. viridis* collected were immatures, while the *H. pistaciae* population comprised only 65 % immatures. *H. pistaciae* also displayed more steady patterns of increase or decrease than *P. viridis* throughout the season.

Table 3. Sørensen's quotient values for spider populations and guilds collected in three pistachio orchards in the Prieska district, Northern Cape Province.

Guild[a]	GVN 1/GVN 19	GVN 19/REM	GVN 1/REM
Total population	0.684	0.789	0.667
PW	0.824	0.778	0.632
GW	0.421	0.667	0.556
OWB	0.667	0.667	0.667
HWB	1.000	1.000	1.000
GWB	0.444	0.857	0.500
SWB	0.750	0.750	0.750

[a]GW = ground wanderers, GWB = gum-foot web builders, HWB = hackle-web builders, OWB = orb-web builders, PW = plant wanderers, SWB = sheet-web builders.

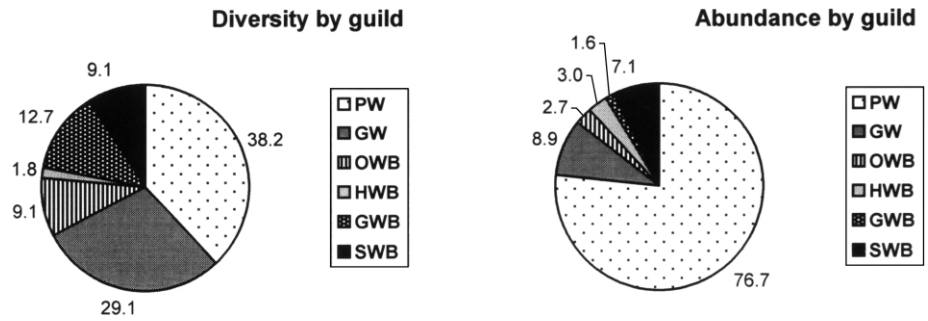

Fig. 1. Guild composition of spider populations in ground covers of pistachio orchards in the Prieska district, Northern Cape Province, with reference to percentage diversity and abundance. GW = ground wanderers, GWB = gum-foot web builders, HWB = hackle-web builders, OWB = orb-web builders, PW = plant wanderers, SWB = sheet-web builders.

Influence of vegetation structure

The percentage representation of the five dominant agrobiont species varied between orchards (Fig. 4), indicating some degree of preference by individual species for different vegetation structures. *P. viridis* was equally abundant in the three orchards and seemed to concentrate on any available vegetation, but particularly herbs and weeds. The jumping spiders *H. pistaciae* and *Phlegra* sp. showed distinct preferences for particular plant compositions and densities. The former species preferred dense and moderately dense plantings where movement between plant foliage is easier, as in the predominantly mixed planting orchards (GVN 1 and REM). The latter is largely surface-active, but occasionally wandered onto plants, and was more abundant in the orchards with at least some space between plants (GVN 1 and GVN 19). Since these three species were among the most commonly found, providing ground covers of similar composition to GVN 1 may yield the greatest benefits for increasing their populations.

T. stenningi and other crab spiders were most

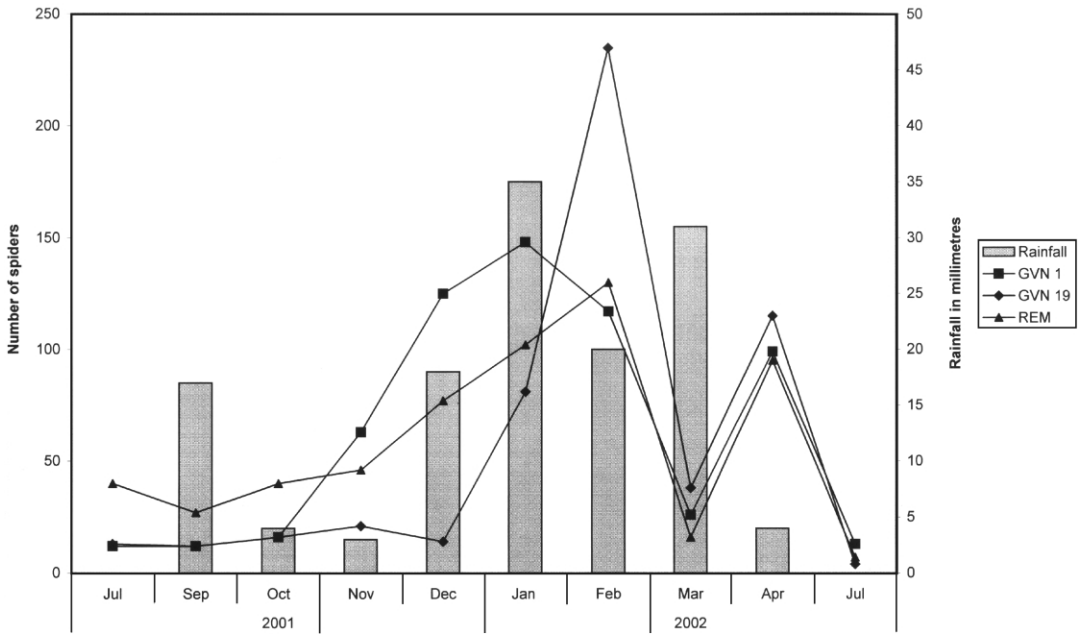

Fig. 2. Seasonal fluctuations of spider populations in ground covers in three pistachio orchards in the Prieska district, Northern Cape Province, over a period of a year.

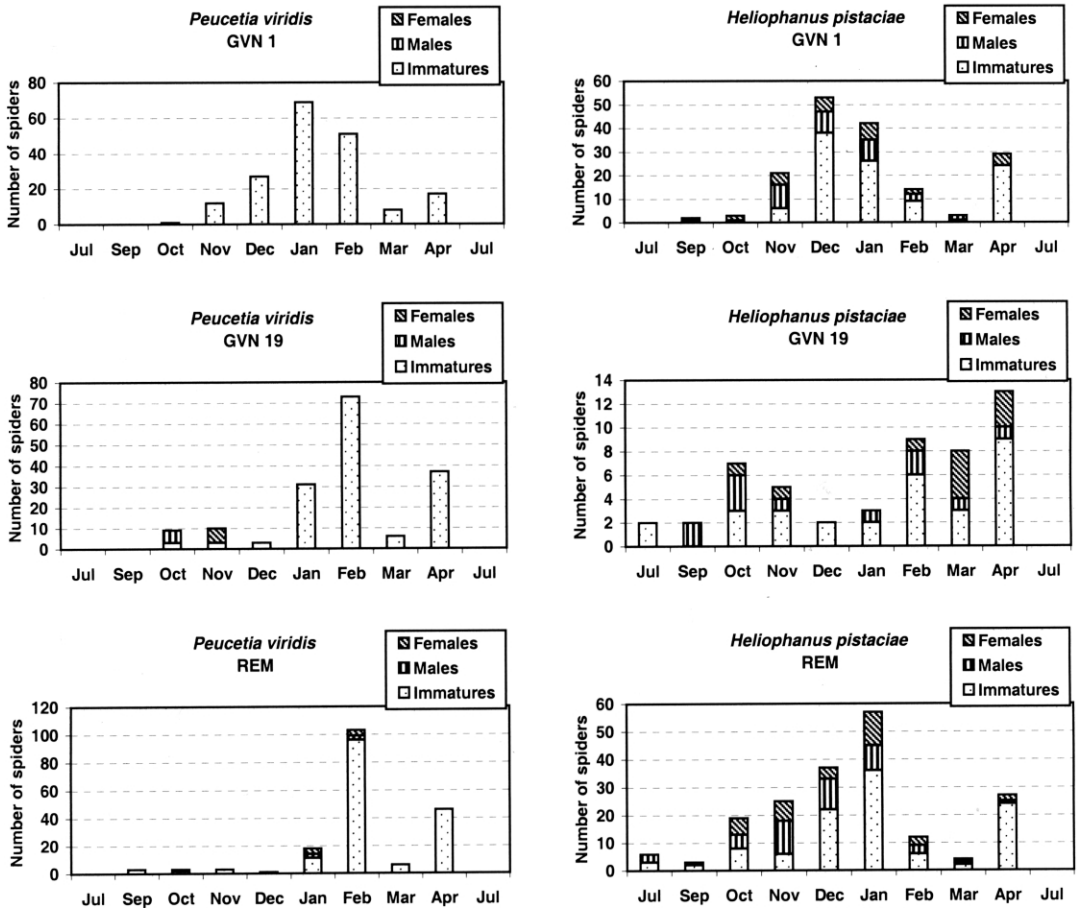

Fig. 3. Seasonal fluctuations of *Peucetia viridis* and *Heliophanus pistaciae* in ground covers of three pistachio orchards in the Prieska district, Northern Cape Province, over a period of a year.

abundant at GVN 19, which could be attributed to the presence of alternate rows of grasses and weeds. This mixed vegetation complex provided a greater variety of niches to be occupied by this group. Included were typical grass-dwelling species (*T. stenningi, Thomisus machadoi* Comellini *Misumenops rubrodecoratus* Millot and *Heriaeus* sp.), as well as flower-dwelling species (primarily *Thomisus* spp.).

The dominant web-building spider in the ground covers, *Ostearius melanopygius* (O P-Cambridge), while not strongly dominant (4.6 % of the total), was more prevalent at GVN 1 than at GVN 19 and REM. This may have been due the vegetation structure at GVN 1, comprising mostly herbs and short weeds, providing suitable web sites close to the ground at the base of vegetation, and/or to the strong colonisation ability of this species from wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) fields adjacent to the orchard.

Predation events

Although spiders were found preying on nine orders of insect prey, namely Collembola, Orthoptera, Thysanoptera, Hemiptera, Homoptera, Coleoptera, Diptera, Lepidoptera and Hymenoptera, and also other spiders, only data on the eight taxa most frequently observed in the chelicerae of spiders are presented here (Table 4).

Spiders were found to prey on a variety of minor pests, as well as on certain taxa of beneficial arthropods. At least six spider species were observed preying on minor pest thrips (Thysanoptera: Phlaeothripidae), leafhoppers (Homoptera: Cicadellidae), aphids (Homoptera: Aphididae) and false chinch bugs (*Nysius natalensis*

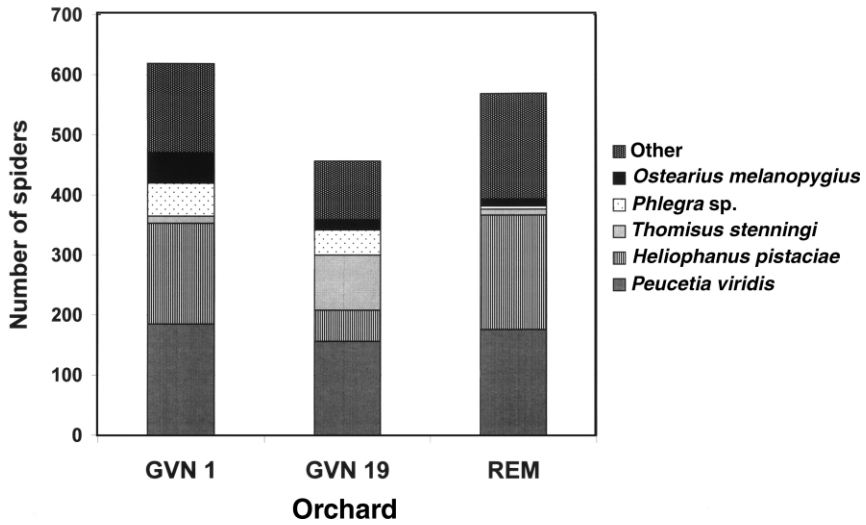

Fig. 4. Relative abundance of five numerically dominant spider species in the ground cover layer of three pistachio orchards in the Prieska district, Northern Cape Province.

Evans, Hemiptera: Lygaeidae). In addition, spiders were occasionally also observed preying on leaf beetles and flies.

The most frequently attacked natural enemies were parasitoids (Hymenoptera: Chalcidoidea). Four spider species were seen capturing small immature thomisids and philodromids (Table 4). On two occasions, *H. pistaciae* and *Philodromus* sp. were also seen feeding on the small ladybird species *Scymnus levaillanti* Mulsant (Coleoptera: Coccinellidae). Since most predation events observed were on pest species, the impact of spiders on other natural enemies may be minimal.

Discussion

This study has shown spiders to be a diverse and abundant arthropod group in ground cover layers in the pistachio orchards surveyed. Dominant species responded differently to vegetation type, although a preference for weedy and herbal vegetation was apparent. It is known that the nature and density of ground covers affect spider phenology differently. More complex habitats provide a greater diversity of structures for web-building spiders to construct webs (Wyss et al. 1995). This was reflected in the greater abundance and diversity of spiders at GVN 1, an orchard dominated by weedy and herbal growth, which creates the most complex habitat structure. This, in turn, may be related to more luscious vegetation, which supports a greater diversity of herbivorous and saprophagous insects. Flowering plants attract large numbers of insects that provide a variety of prey for spiders, hence increasing their rate of survival (Costello & Daane 1998b).

Mowing of ground covers is likely to affect populations of spider groups differently. Howell & Pienkowski (1971) found no differences in numbers of orb-web builders (Tetragnathidae) and nocturnal wolf spider species (Lycosidae) following the cutting of lucerne (*Medicago sativa* L.). Populations of diurnal wandering spiders (Salticidae, Thomisidae), however, decreased whereas sheet-weavers (Linyphiidae) increased after cutting. In the present study the entire spider population showed a marked decrease following ground cover mowing in March, but recovered somewhat in April. Horton (1999) found that spider and parasitoid populations were increased arboreally in pear (*Pyrus communis* L.) trees by decreasing mowing frequency, but this also resulted in an increase in arboreal spider mite populations. Attention should therefore be given to the timing and frequency of mowing to restrict negative effects on spiders and avoid pest proliferation. An effective management strategy (presently in place at GVN) that maintains a clear space, free of any ground cover vegetation, beneath the trees is also important as encroachment by understorey vegetation may reduce yield and vigour of the trees (Brown et al. 1997b; Costello & Daane 1997).

Table 4. Most frequently encountered field observations of predation events involving spiders inhabiting ground covers in pistachio orchards in the Prieska district, Northern Cape Province.

Spider species	Insect prey							
	Thysanoptera: Phlaeothripidae	Hemiptera: Lygaeidae	Homoptera: Aphididae	Homoptera: Cicadellidae	Coleoptera: Chrysomelidae	Diptera: Ephydroidea	Hymenoptera: Chalcidoidea	Other Araneae
Archaeodictyna sp.	+		+	+				
Cheiracanthium furculatum	+	+	+	+	+	+		+
Heliophanus pistaciae	+	+	+	+		+	+	
Neoscona subfusca	+		+	+			+	
Peucetia viridis	+	+	+					+
Pardosa crassipalpis		+	+		+			
Philodromus spp.	+	+	+	+			+	+
Phlegra sp.	+	+	+	+	+	+	+	
Thomisus spp.	+	+	+	+			+	+

There is conflicting evidence regarding the relationship between faunas of ground covers and tree canopies. Spider species composition of ground covers and canopies in orchards may differ considerably (Samu et al. 1997; Costello & Daane 1998b), or there may be a large degree of overlap (Bogya et al. 1999, 2000; Pekár 1999; Rieux et al. 1999; Miliczky et al. 2000). Bogya et al. (1999, 2000) suggested that the presence or absence of ground covers does not significantly influence the abundance or species richness of spiders arboreally. However, 87.3 % of the spider species collected from ground covers in the present study were also present in the tree canopies (Haddad 2003), with *H. pistaciae* accounting for 23.4 % of the spiders in the ground covers and 53.8 % of the canopy fauna. Considering the degree of species overlap, it appears that ground covers in pistachio orchards in South Africa may play an important role in supplementing the arboreal spider fauna, hence assisting in the recovery of arboreal populations depleted by chemical treatments (Rieux et al. 1999; Bogya et al. 2000). This is supported by the decrease in populations of *H. pistaciae* in the ground covers at GVN 1 and REM following a peak in December/January, and subsequent increase in *H. pistaciae* numbers in the tree canopies to a peak in March–April (Haddad 2003). Other scenarios, besides the above overlap between arboreal and ground cover populations of *H. pistaciae,* that could be deduced regarding the correlation between ground cover and arboreal spider faunas (Haddad 2003) in pistachio orchards include the following: (i) distinct dominance in ground covers, while being scarce in the tree layer, e.g. *P. viridis,* (ii) rare in ground covers but common in tree tops, e.g. *Cheiracanthium furculatum* Karsch, (iii) scarce in both ground covers and tree layers, e.g. *Rothus vittatus* Simon, and (iv) scarce in either the ground cover or tree layer, and absent in the other layer, e.g. *Argiope australis* (Walckenaer) and *Pelecopsis janus* Jocqué, respectively.

All the minor pests observed in the study were also present in most of the pistachio trees sampled (Haddad 2003) and have the potential to attain key pest status if measures to control them are inadequate. Thrips, aphids and leafhoppers can cause extensive leaf damage (abrasion and wilting), thereby reducing the photosynthetic capacity of the plants and, consequently, nutrient conversion and growth. Species such as *N. natalensis* further-

more serves as a vector for fungal pathogens of pistachio (Swart 2002). While not particularly abundant in the tree canopies, *N. natalensis* is very common in ground covers of most orchards, especially when weedy plants such as *Conyza bonariensis* (L.) Cronq. are present. Field trials indicated that a mean of 1.05 *N. natalensis* are killed by *H. pistaciae* (n = 20) per 24 hours, whereas laboratory experiments suggest that *H. pistaciae* kills *N. natalensis* without feeding on it (Haddad et al. 2004), which is a form of wasteful killing (Sunderland 1999). As part of a greater natural enemy complex in the ground cover layer, spiders may therefore play an important role in the suppression of minor pests in this stratum.

Conclusion

The benefits that spider communities have as a predatory complex include the diverse lifestyles of individual species, utilisation of a greater number of niches (resulting in a greater pest control effect in various strata), and the ability to consume all life stages of a pest (Nyffeler et al. 1994; Marc & Canard 1997; Sunderland 1999). Structurally complex ground cover regimes, which have a variety of strata, will provide refuge for different species of predators, thereby minimising the role of intraguild predation (predation of one predator species on another) and maximising the predation impact on commonly utilised herbivorous prey species (Finke & Denno 2002). This implies that pest control effects at ground level would be maximised in orchards with a complex structure, i.e. a mixture of herbs, weeds and grasses, such as GVN 1 and REM in this study.

However, a greater diversity of plant species at ground level could support a greater diversity of herbivorous insects, increasing the risk of non-pest herbivores reaching pest status on the main crop. Such a situation needs to be more closely scrutinised by comparing minor pest populations in pistachio tree canopies in orchards with different ground cover structures.

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