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EFFECTS OF COWPEA (VIGNA UNGUICULATA (L) WALP FARMING SYSTEMS ON ARTHROPOD COMMUNITY STRUCTURE IN A GRASSLAND AGRO-ECOSYSTEM, SOUTH AFRICA

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ABSTRACT

Cowpea (*Vigna unguiculata* (L) is an important grain legume cultivated in tropical and subtropical regions of the world for its high nutritive value and nitrogen-fixing potential. Since cowpea utilization patterns, seed preferences, and cropping system vary from one region to another, constraints to its optimal production by subsistence farmers such as cropping practices and insect pest infestation continue to pose challenges at various spatial and temporal scales. To maximize crop yield quality and quantity, various communities use or practice farming systems that are adapted to their climate, agro-ecology, socio-cultural and economic needs. These practices are being adopted as part of an integrated strategy, aimed at minimizing adverse effects of excessive pesticide usage while encouraging sustainable ecological pest control and higher crop yield. Field experiments were undertaken in the Mhlontlo Municipality, Transkei region of Eastern Cape Province, South Africa during the 2014-2015 cropping season to determine the effects of cowpea farming system on arthropod communities. Five cowpea varieties (TVU-244-9, TVU-170-6, TVU-659-6, TVU-455-7 and Ife-Brown) were planted using a split-plot experimental design in four replications and two farming systems (conservation and conventional) as main plots, and cowpea varietal treatments as subplots. A total of 8 orders, 17 families and 20 species of arthropods were recorded. Overall, higher species richness trends were observed at conservation sub-plots. Significant differences ($P<0.05$) were obtained for total arthropod population count amongst cowpea varieties and farming system, whereas the interaction between cowpea varieties and farming system for beneficial arthropods was not significant ($P>0.05$). Also, Significant ($P<0.05$) differences were observed for pest species populations across trial plots. All cowpea varieties were susceptible to insect pest infestation irrespective of farming system. Cowpea variety TVU-244-9 had the highest insect pest population count at conventional and conservation plots. Conservation plots provided more optimal habitat requirements for a broad spectrum of arthropod assemblages including natural enemies (predators and parasitism), pollinators and decomposers. The study, therefore, recommends conservation agriculture as a complementary method for cultivating cowpea especially in subsistence farming communities of the Transkei region of South Africa.

Key words: Arthropod, community, cowpea, varieties, farming system, species richness

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INTRODUCTION

Cowpea (*Vingna unguiculata* (L) Walp) forms part of the major grain legumes traditionally grown in Africa, Asia, Central and South America mostly as an intercrop because of its ability to fix up to 80% nitrogen from the atmosphere [1,2,3]. Residual nitrogen originating from the decay of its leaves, roots and root nodules provide soil nutrients for other crops [4]. In the Transkei region of South Africa, cowpea is grown as a subsistence crop and major source of cheap plant protein [5]. Among the constraints to cowpea production are heavy field infestations by insect pests such as aphids, lepidopteran larvae, blister beetles and pod sucking bugs that have also been recorded in the Transkei region [6,7,8]. Farming systems as defined in this study refer to agricultural practices often used by subsistence farmers to obtain optimal and sustainable crop yields. It is important to design farming systems that mimic natural systems in order to enhance sustainable crop productivity [8]. To maximize crop yield quality and quantity, various communities use farming systems that are adapted to their climate, agro-ecology, socio-cultural and economic needs [9]. These practices are being adopted as part of an integrated strategy, aimed at minimizing adverse effects of excessive pesticide usage while encouraging sustainable ecological pest control and high crop yields [10, 11]. This study was, therefore, undertaken to determine the effects of cowpea farming systems (conventional and conservation) on arthropod community structure in a grassland agroecosystem in the Transkei region of South Africa.

MATERIALS AND METHODS

The study was undertaken during the 2014-2015 cropping season at trial and demonstration plots in Tsolo Agricultural and Rural Development Institute located at 31°, 17’ S; 28°, 45’ E in the Mhlontlo Municipality of the Transkei region, Eastern Cape Province of South Africa. This area receives an average annual rainfall of 749 mm, with most rainfall occurring during summer, while lowest average rainfall (15 mm) is experienced during winter. Average annual temperatures range from 3.2 °C in June to 26.5 °C in January [12, 13].

Procedure, treatment and crop management

Five improved cowpea varieties of TVU-2449, TVU-1706, TVU-6596, TVU–4557 and Ife-brown were planted using a split plot experimental design with four replications and two farming systems (conservation and conventional) as main plots. The main plots measured 19 m x 5 m, with a spacing distance of 2 m, while subplots were 3 m x 2 m with a spacing distance of 1 m. Cowpea seeds were soaked in water for 12 hours to enhance germination and initial plant growth [13]. Viable seeds of each variety were planted at three seeds per hole with 30 cm spacing between holes and 60 cm between rows [14]. Thinning of seedlings to one plant per hole was done at 10 days after seedling emergence. Each subplot consisted of 4 rows of 10 cowpea plants per row. Conventional plots were cleared, tilled manually and fertilized by broadcasting with 50g of NPK fertilizer (15:30:15) at subplots during the planting stage (83Kg/ha). Plots were sprayed with Kemprin 200 EC (active ingredient cypermethrin, 2.5ml/10L of Knapsack) that was split into two doses each of 5L/380m^2, one at flowering stage and another during pod-set to control insect pests at the rate of 263L/ha. Even though

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conservation plots were neither tilled nor fertilized, they were mulched with grass that was cleared from plots and *in-situ* weeding done at these plots. Regular weeding was undertaken at all trial plots to ensure that cowpea plants developed under non-limiting conditions.

Data collection

Data on arthropod assemblages was collected weekly throughout the crop cycle from three weeks after planting (WAP) until harvest at maturity. This was carried out through visual monitoring, hand picking and counting of arthropod specimens (insect pest and beneficial arthropods excluding mites) within a five-minute interval at each cowpea subplot from 08:00 am to 12:00 noon during each sampling occasion. Observations on insect pest infestation and beneficial arthropods commenced at three weeks after seedling emergence, between 08:00 am to 12:00 noon on six randomly selected cowpea plants from the two middle rows of each subplot. Aphid colony size was visually scored based on a scale of 0 (no infestation), 1(1-4, a few individual aphids), 3 (5-20, a few isolated colonies), 5 (21-100, several small colonies), 7 (101-500, larger isolated colonies), and 9 (>500, large continuous colonies) [15]. Three observations each were made before spraying at pre-flowering, flowering and at pod-formation stages.

Statistical analysis

All data recorded followed a split-plot factorial design with replication, and were subjected to analysis of variance (ANOVA in SPSS software version 20) to test for significant differences (if any) in total arthropod species richness, insect pest and beneficial arthropod population count across trial plots. Means were separated by Fisher Least Significant Difference Test (LSD) at 5% level of probability. Univariate methods in Excel were used to measure arthropod indices of diversity and evenness across cowpea trial plots.

RESULTS AND DISCUSSION

Taxonomic profile of arthropod assemblages during the trial period

A total of eight orders, 17 families and 20, species were recorded throughout the cropping season (Table 1a, b), while some of the orders recorded have also been observed by several authors in the tropical and subtropical regions of Africa including the Transkei area [7,16,17, 18]. Conservation subplots had overall higher species richness and individual arthropod counts (Table 2a) than conventional ones. There were statistically significant ($P<0.05$) differences in overall arthropod individual count as well as pest and beneficial arthropod count amongst cowpea subplots under conservation and conventional cropping systems. However, there were no significant differences ($P>0.05$) recorded on the interaction between cowpea variety and farming system for total number of arthropod population count at trial plots (Table 2c). Beneficial arthropods sampled included pollinators like *Apis millifera* (Apidae: Hymenoptera) and *Sarangesa motozi* (Hesperiidae: Lepidoptera), predators (*Rhinocoris segmentarius* (Reduviidae: Hemiptera), *Harmonia vigintiduomaculata* (Coccinelidae: Coleoptera), *Bolonogaster dubai* (Vespidae: Hymenoptera), *Pantala flavescence* (Libelluidae: Odonata), spiders (Araneae) and decomposers like *Diplognatha gagates*

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(Scarabaeidae: Coleoptera) (Table 1a). Some important pest species sampled included *Aphis craccivora* (Aphididae: Homoptera), Pod-sucking bugs, *Nezara viridula* (Pentatomidae: Hemiptera), *Anoplocnemis curvipes* (Coreidae: Hemiptera), locusts. *Locustana pardalina* (Acrididae: Orthoptera) stem borers. *Maruca testulalis* (Pyralidae: Lepidoptera) and pod borers *Mylabris oculata* (Meloidae: Coleoptera) (Table 1b). Higher species richness counts recorded at conservation plots than conventional plots may be attributed to the fact that conservation farming incorporates agro-biodiversity elements such as nutrient retention capacity for soil surface dwelling species, as well as increased species and genetic diversity across multiple spatial and temporal scales that characterised conservation subplots in the current study [11]. Mulching at conservation plots probably aerated soil organic matter, providing favourable conditions for symbiotic microbial activities, which may have been beneficial to epigaeic arthropods [19,20]. The removal of weeds and use of inputs such as fertilizer and pesticides in conventional plots probably caused a reduction in some arthropod species, negative impacts on non-target species and habitat loss [21]. These factors may have adversely affected agro-ecological processes at subplots in this study [22,23]. Furthermore, tillage implemented in conventional plots, probably resulted in arthropod species exposure to various predators and weather factors such as desiccation, direct irradiation from sunlight especially on immature stages of arthropods as well as reduction in habitat complexity required by some arthropod species. Soil organic matter being oxidized when exposed to air, disrupts soil structure and microbial activities that is essential for root development and growth of cowpea plants [22].

Arthropod species richness and abundance increase from seedling to maturity stage among cowpea varieties and farming system (Fig.1a, b) suggests that fewer insects specialized in leaf consumption [24]. Higher population counts of insect pests, *Mylabris. oculata, Decapotoma. lunata, Lytta. nitidula, Diplognatha. gagates, Aphis craccivora* and *Nezara. viridula* occurred at the flowering and post-flowering stages. This was probably due to the greater availability of pollen and nectar which attracted high population densities of insect pests *Mylabris oculate,* which had the highest population count at conservation plots than conventional plots and beneficial arthropod species like bees [25,26] as recorded the most at conservation plots. High population counts of some members of the Coleoptera and Hymenoptera in this study can be explained by the fact that these taxa have a predilection for cowpea plant inflorescence that are also suitable for feeding, basking and mating sites [27]. The presence of pod sucking bugs on fresh pods during pod set and pod formation as feeding preferences [28] may have also contributed to the increase in population trend at these growth stages of the crop. According to Ajeigbe *et al.* [29], two to four spray regimes at seven-day intervals are required to potentially reduce pest population to ensure better cowpea crop yield. In the current study, one spray regime was implemented at the early stage of flowering and at the early stage of pod set at conventional plots. This may not have been sufficient in reducing arthropod pest infestations to levels below acceptable damage thresholds, even though spraying may not necessarily reduce pest species population count partly due to insecticide resistance, amongst other factors.

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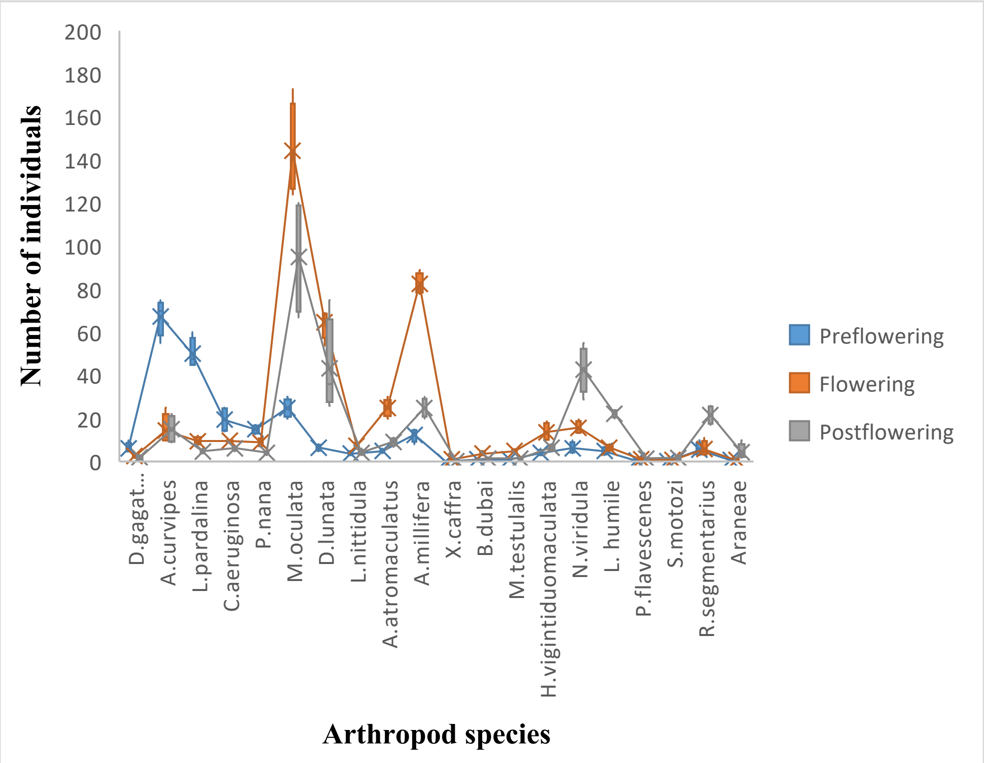

Figure 1a: Effects of crop phenology arthropod species across trial plots

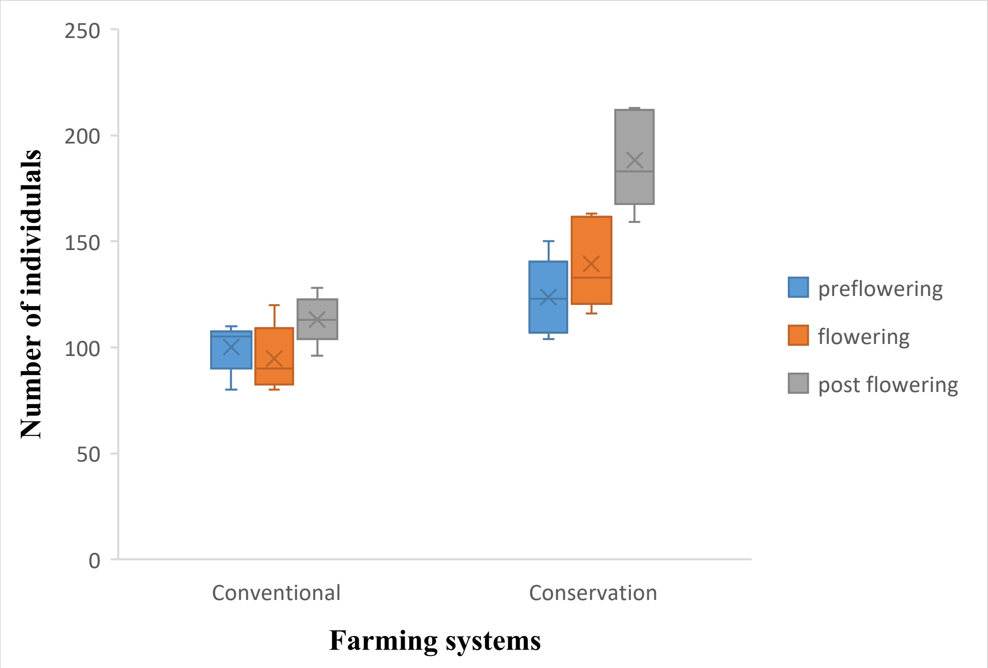

Figure 1b: Effects of crop phenology on arthropod individuals across farming systems

Incidence of insect pest population on cowpea varieties at trial plots

Higher insect pest species and individuals were recorded throughout the cropping season, with overall higher incidence of the same pest species recorded at conservation plots. There were significant (P<0.05) differences in pest population count among cowpea varieties, as well as the interaction between cowpea variety and farming system across trial plots (Table 2a, c). The higher incidence of insect pest species and population counts at conservation plots than conventional plots (Fig. 2) may be attributed to the fact that microhabitat in the conservation farming plots provided more optimal habitat requirements for both pests and beneficial insects [30]. Cowpea variety TVU-244-9 had the highest insect pest population counts in conventional and conservation plots compared to the other varieties. This may be due to its growth morphology longer pods and more exposed surface area to pest infestation [31]. Furthermore, it is an early maturing variety compared to the other varieties and therefore probably more susceptible to pest infestation [3]. All cowpea varieties were susceptible at varying degrees to insect pest infestation under the two farming systems, suggesting that none of the sub-tropically adapted varieties used in the study were resistant to insect pest infestation. Similarly, Luka *et al*. [18] reported differential susceptibility to field infestation by insect pests such as *Megalurothrips sjostedti*, *Maruca testulalis*, *Mylabris* spp, and *A. curvipes* to some improved cowpea varieties: Iron beans, Samira, BOSADP, Kanannado and Ife-brown. However, Baidoo & Mochiah [32] showed that there were no significant differences in susceptibility of some improved cowpea varieties to field pests such as *A. craccivora*, *M. sjostedti* and pod sucking bugs.

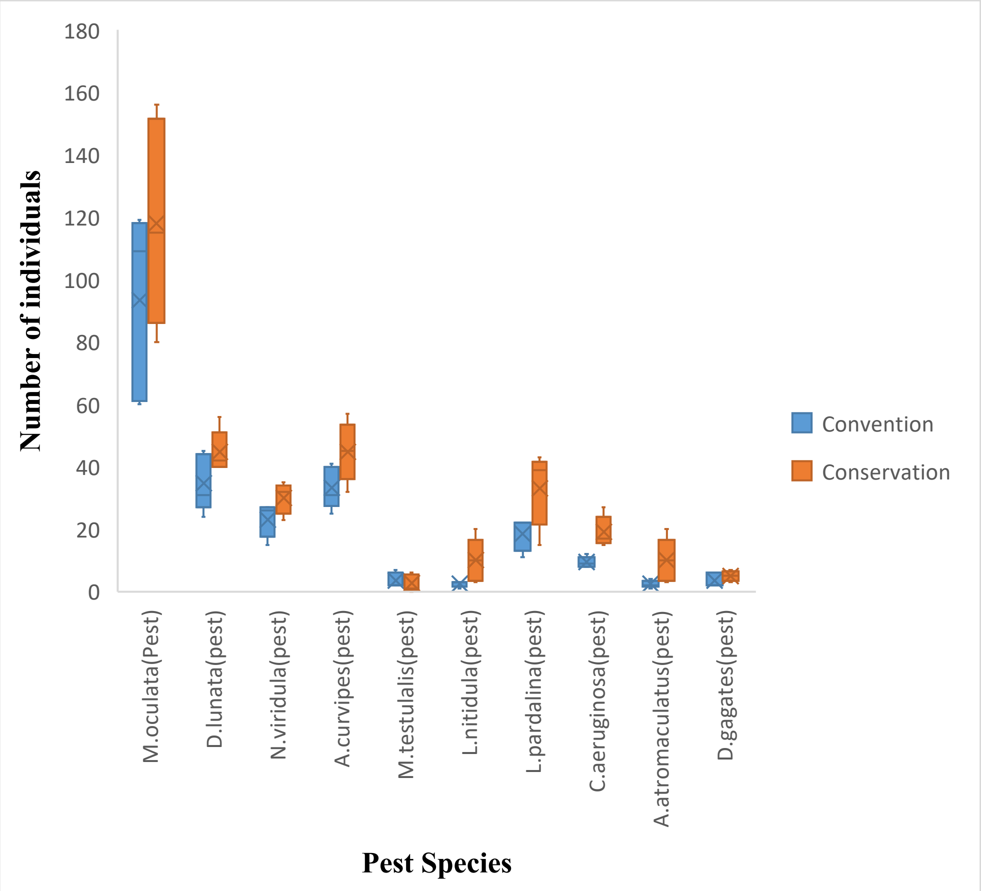

Figure 2: Insect pest species recorded across trial plots

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Beneficial arthropods recorded at trial plots

Higher numbers of beneficial insect species were recorded in conservation plots than conventional plots and cowpea variety TVU-244-9 had the highest population counts compared to the other varieties (Table 2a), with significant difference (P<0.05) across farming systems, even though not significant (P>0.05) in the interaction between farming system and cowpea variety (Table 2c). This may be attributed to higher prey densities at conservation plots which probably accounted for higher predator (natural enemy), pollinator (*Apis millifera*) and predator abundance for some species (for example, *Linepithema humile, Harmonia vigintiduomaculata, Rhinocoris segmentarius*), leading to overall higher population counts of beneficial insects at conservation plots (Fig 3) during the sampling period [17]. However, beneficial insects at conservation plots belonged to different ecological *niches* and guilds that may not have been directly affected by spray regimes used in the study.

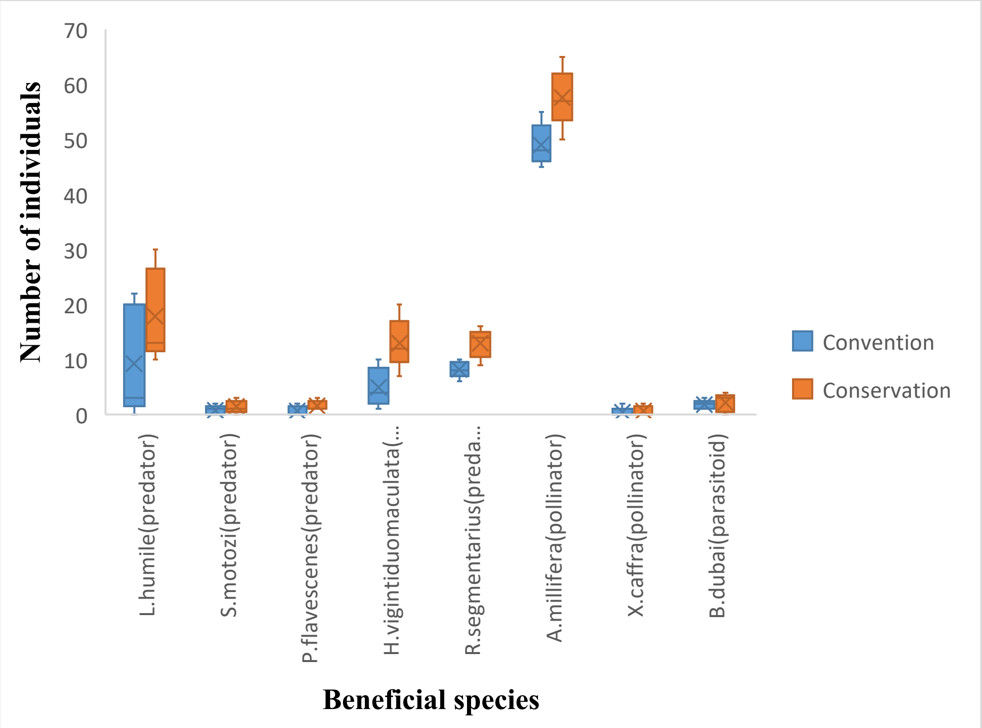

Figure 3: Beneficial arthropods recorded across trial plots

CONCLUSIONS

All cowpea varieties in the study were susceptible to insect pest infestation irrespective of the farming system used. Higher arthropod populations were recorded at conservation plots. This farming system offered more optimal habitat requirements for a broad spectrum of arthropod assemblages and feeding guilds, such as predators, parasitoids (natural enemies and biological control agents), pollinators and decomposers. Cowpea crop yield quality and quantity can be maximized with the implementation of farming systems that minimize excessive use of pesticides while encouraging ecological pest control in the face of increasing adverse impacts of climate change and anthropogenic factors. This study, therefore, recommends the practice of conservation farming methods to complement conventional ones especially in rural communities of the Eastern Cape Province of South Africa where subsistence agriculture is mostly practiced. However, challenges of controlling usually heavy pest infestations associated with cowpea flowering, pod set and maturity stages in practice remain.

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Table 1a: Taxonomic Profile of beneficial arthropods recorded at trial plots of cowpea varieties

Order	Family	Scientific name	Common name	Con plot (N)	H`=Shannon Diversity indices H`=(pi*ln(pi)	CA plot (N)	H`=Shannon Diversity indices H`=(pi*ln(pi)	Observed Association
Coleoptera	Coccinellidae	*Harmonia vigintiduomaculata* (Fabricius,1792)	Ladybird beetles	25	0.191	66	0.258	Predator (feeds on aphids)
Hemiptera	Reduviidae	*Rhinocoris segmentarius* (Germar,1837)	Assassin bugs	41	0.255	65	0.256	General predator (feeds on aphids and caterpillar)
Hymenoptera	Apidae	*Apis millifera* (Linnaeus,1758)	Honey bees	204	0.306	276	0.341	Pollinators
	Anthophoridae	*Xylocopa caffra* (Linnaeus,1767)	Carpenter bees	2	0.030	3	0.029	
	Vespidae	*Bolonogaster dubai* (Kohi, 1894)	Bee wasps	7	0.079	10	0.074	Lepidopteran predator/ Nectar
	Formicidae	*Linepithema humile* (Mayr,1868)	Black ants	46	0.271	89	0.298	General predators
Araneae	Unidentified	Unidentified	Spiders	8	0.088	10	0.075	General predators
Lepidoptera	Hesperiidae	Sarangesa motozi (Wallengren, 1857)	Elfin skipper	4	0.052	7	0.057	Predator (feeds on *Barleria, Justicia* and *peristrophe species*)
Odonata	Libelluidae	*Pantala flavescenes* (Fabricius, 1798)	Wandering glider	3	0.042	8	0.063	General predators
Total				340	1.317	534	1.452	
Evenness	H/H max				0.599		0.662	

"Con" = Conventional plots, "CA" =Conservation plots, "N" =number of individual species counts

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Table1b: Taxonomic profile of arthropod pests recorded at trial plots of cowpea varieties

Order	**Family**	**Scientific name**	**Com Name**	**Con plot (N)**	**H`=Shannon Diversity indices H`=(pi*ln(pi)**	**CA Plot (N)**	**H`=Shannon Diversity indices H`=(pi*ln(pi)**	**Infestation stage**
Coleoptera	Meloidae	*Mylabris oculata* (Thunbeng, 1791)	Beans beetle	467	0.368	590	0.367	Flowering stage (adults feed on fresh flower heads / petals reducing pod set).
		Decapotoma lunata (Kszab,1961)	Blister beetle	174	0.278	224	0.267	
		Lytta nitidula (Fabricius,1775)	Green beetle	12	0.046	50	0.267	
	Melyridae	*Astylus atromaculatus* (Blanchard,1843)	Spotted maize beetle	59	0.046	98	0.104	
	Scarabaeidae	*Diplognatha gagates* (Forster,1771)	Large black nest chafer	18	0.062	25	0.165	Pre-flowering, flowering podding stage (adults feed on green leaves, flowers, fruits and sap).
Homoptera	Aphididae	*Aphis craccivora* (Koch, 1854)	Aphid	>500	>500	>500	>500	All stages (sucking plant sap causing wrinkled leaves, decreasing flower and pod production)
Hemiptera	Pentatomidae	*Nezara viridula* (Linnaeus,1758)	Green vegetable bug	115	0.223	150	0.062	Vegetative stage (feeds on young leaves, growth point and podding stage (feed on pods).
	Coreidae	*Anaplocnemis curvipes* (Fabricius,1781)	Twig wilter	166	0.223	224	0.267	Vegetative stage (pierce young shoots injecting saliva causing shoots to shrivel beyond the puncture).
Orthoptera	Acrididae	*Locustana pardalina* (Walker,1870)	Brown locust	92	0.195	165	0.227	Vegetative stage (adults feeds on leaves)
		Crytacanthacris aeruginosa (Kary,1907)	Grasshopper	47	0.126	96	0.162	
	Tettigoniidae	*Phaneroptera nana* (Fieber,1853)	Green bush Cricket	50	0.131	62	0.121	Vegetative stage(adult feeds on leaves)
Lepidoptera	Pyralidae	*Maruca testulalis* (Geyer,1832)	Pod borer	18	0.062	13	0.037	Flowering stage
Total				1218	1.909	1697	1.994	
Evenness	H /H max				0.796		0.832	

‘Con” = Conventional plots, “CA” =Conservation plots, “N” =number of individual species counts

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Table 2a: Mean number of arthropod species (S) and individual counts (N) counts, diversity indices and evenness across trial plots. P-values are given at 5% level of probability

	Convention plot				Conservation plot					
Varieties	Means	Species (S)	Individuals (N)	Shannon diversity (H)= -∑[pi*ln pi	Means	Species(S)	Individuals (N)	Shannon diversity (H)= -∑[pi*ln pi	Total (N) individuals	Total % (%N)
TVU-244-9	98.75±26.94a	20	395	-0.3454	156.75±16.72a	20	627	-0.3329	1022	27.0
TVU-170-6	79.00±16.77b	19	316	-0.3401	97.75±20.55c	19	391	-0.3270	707	18.6
TVU-659-6	66.50±17.23d	15	266	-0.3123	98.75±24.72c	18	395	-0.3205	661	17.4
Ife-Brown	72.50±11.27c	14	290	-0.3034	114.50±23.27b	18	458	-0.3205	748	19.7
TVU-455-7	65.75±18.03d	13	263	-0.2935	98.50±19.43c	16	394	-0.3056	657	17.3
Total	382.5±90.20a	81	1530	1.5945	566.25±104.69b	91	2265	1.6065	3795	100
Evenness=H/ Hmax				0.9907				0.9981		

Means in the same column with the same letter(s) are not significantly different (P≥0.05), ± Standard deviation, LSD=5

Table 2b: Mean number of arthropod pests and beneficial arthropods at conventional and conservation plots-values given at 5%level of probability

Mean number of Arthropod pest individuals per cowpea varieties				Mean number of beneficial arthropods observed across trial plots	
Varieties	code	Convention plot	Conservation plot	Convention plot	Conservation plot
TVU-244-9	V1	76.75±24.91a	122.50±9.57a	22.25±2.06	34.25±7.80
TVU-170-6	V2	62.75±16.32b	74.50±17.33c	16.25±5.06	26.25±3.95
TVU-659-6	V3	48.25±14.27d	77.25±24.01c	18.25±7.59	21.50±3.87
Ife-Brown	V4	58.00±13.59c	88.00±12.52b	14.50±3.51	21.75±5.91
TVU-455-7	V5	47.75±12.18d	73.00±11.75c	18.50±8.23	25.50±7.85
Total		293.5±81.27	435.25±75.18	89.75±26.45	129.25±29.38
LSD		4.6	4.6	NS	NS

Means in the same column with the same superscript are not significantly different (P≥0.05), ± Standard deviation

Table 2c: Mean square values of arthropod assemblage dynamics recorded across trial plots P-values are given at 5% level of probability

Source	D f	Total arthropod individual count	Arthropod pest individual count	Beneficial arthropod
Replication	1	483.605 ^{ns}	103.680 ^{ns}	2.420 ^{ns}
Farming systems	1	13505.625*	9302.500*	624.100*
Error a	5	991.989	654..844	80.056
Variety	4	1589.182*	858.692*	39.225 ^{ns}
Variety*Farming system	4	419.687 ^{ns}	528.812*	22.037 ^{ns}
Variety *Replications	4	450.642 ^{ns}	297.692 ^{ns}	14.357 ^{ns}
Error b	20	235.881	169.616	30.319
LSD		5	4	7

‘ns’ indicate not significant at (P>0.05) and * indicates significance at (P<0.05) across trial plot

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