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# Spiders as Bioindicators: Evaluating Environmental Health and Habitat Quality in the Agricultural Landscapes Around Digras Town

**Dr. Narendra A. Manwar**
*Department of Zoology, B.B. Arts, N.B. Commerce and B.P. Science college, Digras, Maharashtra*
*naruzoology@gmail.com*

**Abstract**
*This study evaluates the utility of spider (Araneae) assemblages as ecological bioindicators to assess environmental health, microclimatic variance, and habitat quality across diverse agricultural matrices surrounding Digras town, Yavatmal district, Maharashtra, India. Over a 12-month field investigation spanning the Kharif, Rabi, and Zaid crop seasons, arachnid diversity and abundance were monitored across three distinct management zones: Conventional Intensive Agriculture (CIA), Low-Input Sustainable Agriculture (LISA), and Undisturbed Natural/Riparian Buffer Zones (URBZ). Using pitfall trapping, sweep netting, and hand collection, a total of 1125 individual spiders representing 6 families and 27 species were recorded. Significant variations in community structure were observed; the family Salticidae (stalkers) and Araneidae (orb-web weavers) exhibited the highest overall abundance. Diversity indices (Shannon-Wiener $D$ and Simpson's ) peaked within URBZ and LISA systems, while dropping markedly in CIA zones subjected to frequent synthetic chemical applications. Cursorial groups, particularly the Lycosidae, demonstrated highly specific structural adaptations, developmental variations, and sensitivity to soil compaction and pesticide toxicity.*
***Keywords:*** *Araneae, Bioindicators, Agroecosystems, Digras, Habitat Fragmentation.*

## 1. Introduction

Bio-indicators are taxa or functional groups which reflect the state of the environment (Lencinas et al. 2015). Bio-indicators are useful for conservation prioritisation by means of spatial comparisons of a site value, or monitoring of ecosystem recovery or response to management decisions (Peri et al. 2016; Schwerdt et al. 2018).Modern agricultural modernization relies heavily on synthetic inputs, heavy machinery, and monoculture cropping systems, resulting in worldwide declines in terrestrial biodiversity, soil degradation, and altered trophic networks. To mitigate these impacts, landscape managers require sensitive biological tools capable of functioning as early-warning metrics for ecological stress. Bioindicators—taxa or functional groups that visibly reflect the structural or functional integrity of an ecosystem—offer a holistic assessment method compared to isolated physicochemical testing. Since the early 1990s, numerous studies, particularly originating from Europe, have extensively investigated their ecological functions and structural benefits in intensive agricultural landscapes. Within terrestrial macroinvertebrate communities, spiders (Order: Araneae) comprise one of the most diverse, high-biomass groups of predatory generalists. Spiders exhibit structural traits that position them as strong candidates for ecological monitoring:

- **Trophic Position:** As obligatory predators, they occupy mid-to-high trophic levels within invertebrate webs, accumulating energy and pollutants from lower prey levels.
- **Sensitivity:** Their reproductive output, web-building mechanics, and locomotor behaviors are highly sensitive to microclimatic anomalies and low-level chemical drift.
- **Guild Specialization:** They organize into distinct functional guilds (e.g., ground runners, orb weavers, stalkers), allowing them to mirror spatial changes across ground, canopy, and understory niches.

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## 2. Materials and Methods

### 2.1 Study Area:

Digras town is located in the semi-arid Vidarbha region of Maharashtra, India. The area features a tropical wet-and-dry climate characterized by black cotton soils (vertisols) that support cash crops, primarily cotton (*Gossypium hirsutum*), soybean (*Glycine max*), and pigeon pea (*Cajanus cajan*). Over the past few decades, local farming has shifted toward double-cropping systems reliant on organophosphates, synthetic pyrethroids, and mechanical tillage. This chemical and physical disturbance profile makes the agricultural fringe of Digras an informative setting for assessing spider communities along a gradient of land-use intensity. Fieldwork was conducted across a 15-kilometer radius surrounding Digras town. Sampling areas were categorized into three distinct Land Use Zones (LUZs).

| Zone Code | Environmental Classification | Representative Management Profile |
|---|---|---|
| **Zone I: CIA** | Conventional Intensive Agriculture | High-frequency insecticide usage (e.g., cypermethrin, chlorpyrifos), mechanized tillage, monoculture cotton/soybean. |
| **Zone II: LISA** | Low-Input Sustainable Agriculture | Intercropping (Soybean + Pigeon pea), integrated pest management (IPM), neem-based formulations, minimal tillage. |
| **Zone III: URBZ** | Undisturbed Riparian & Buffer Zones | Secondary vegetation corridors, grass-dominated bunds, and minimal anthropogenic footprints along the Arunavati River basin. |

**2.2 Sampling Design and Collection Techniques:**

To balance capture efficacy across distinct microhabitats, a standardized multi-method sampling design was implemented monthly from October 2025 through September 2026. Each LUZ contained five permanent plots.

- Pitfall Trapping (Epigeic Fauna): Five plastic fluid traps (10cm, 70cm diameter, filled with ethanol and a drop of detergent) were arranged per plot in a cross-pattern. configuration. Traps remained active for 48 consecutive hours per session. Pitfall trapping captures ground runners / epigeic hunters
- Sweep Netting (Foliage Inhabitants): Standardized sweep netting consisted of 50 sweeps along a linear transect through the field crop canopy or shrub layer using a diameter insect net. Sweep Netting captures foliage dwellers & stalkers.
- Visual Search & Hand Collection (Cryptic Niche Extraction): Timed 30-minute direct searches were conducted per plot, covering under-leaf surfaces, bark fissures, and soil cracks. Visual search & hand Collection captures web weavers & cryptic Species

**2.3 Taxonomic Identification and Guild Classification:**

Collected specimens were preserved in 70% analytical grade ethanol. Morphological structures, specifically epigynes and pedipalps, were examined under stereomicroscopes. Taxonomic determinations were completed using standard Indian arachnological literature and keys synchronized with the World Spider Catalog. All identified individuals were categorized into seven primary functional guilds based on foraging biology: Orb Weavers (OW), Space Web Builders (SWB), Foliage Cursorial Hunters (FCH), Ground Cursorial Hunters (GCH), Stalkers (ST), Ambushers (AMB), and Sheet Web Weavers (SWW).

**2.4 Environmental Variables Measured:**

Simultaneously during each sampling session, the following microenvironmental parameters were recorded within each plot:

- **Soil Compaction (**kg/cm$^2$**):** Measured using a cone penetrometer.
- **Canopy and Understory Cover (%):** Evaluated via digital densiometer analysis.
- **Pesticide Application Frequency:** Recorded as cumulative spray events per annum based on field logs.
- **Ambient Microclimate:** Air temperature (◦C) and relative humidity (%) captured via a portable digital hygrometer.

**2.5 Statistical Analysis:**

Arachnid community patterns were examined using the statistical software framework R. Alpha diversity metrics were calculated via the vegan library:

$$\text{Shannon-Wiener Index}(H') = -\sum_{i=1}^{S} p_i \ln p_i$$

Shannon-Wiener Index ($H'$)=$-S\,i=1p\;i\ln p\;i$

$$\text{Simpson's Index}(D) = \sum_{i=1}^{S} p_i^2$$

Simpson's Index ($D$ )=$S\,i=1p\;2i$

## 3. Results:

### 3.1 Taxonomic Abundance and Guild Distribution:

Across the 12-month study, 1125individual spiders were evaluated, yielding 16 families, 38 genera, and 48 distinct species. The distribution of species and families was skewed across the different landscape types.

Total Specimens Collected: 1125

Zone III (URBZ): 448 specimens (Highest richness & balance)

Zone II (LISA): 409 specimens (Intermediate diversity)

Zone I (CIA): 268 specimens (Dominated by highly resilient taxa)

The dominant families by individual count were **Salticidae** (24.5%), **Araneidae** (21%), **Lycosidae** (21%), **Oxyopidae** (14%), Thomisidae (7%) and Tetragnathidae (7%). The complete familywise checklist, along with individuals collected per management zone, is outlined below:

Table 1: Comprehensive familywise Checklist and Abundance Records Across Digras Agroecosystems

| Family | No. of Species | Zone I (CIA) | Zone II (LISA | Zone III (URBZ) | Total |
|---|---|---|---|---|---|
| **Salticidae** | 7 | 69 | 106 | 151 | **326** |
| **Araneidae** | 6 | 56 | 89 | 115 | **260** |
| **Lycosidae** | 6 | 41 | 82 | 102 | **225** |
| **Oxyopidae** | 4 | 35 | 56 | 39 | **130** |
| **Thomisidae** | 2 | 11 | 45 | 25 | **81** |
| **Tetragnathidae** | 2 | 56 | 31 | 16 | **103** |
| **Total Abundance** | | **268** | **409** | **448** | **1125** |

### 3.2 Diversity Indices and Community Structure Assessment:

Calculations of alpha diversity revealed differences in community structure between the highly managed and natural zones. Zone III (URBZ) exhibited the highest Shannon-Wiener index, followed by Zone II, while Zone I displayed lower values due to high dominance by a few tolerant taxa.

Diversity Metric Gradient Across Management Intensities:

Shannon-Wiener (H')

Zone I (CIA) ■■■ 1.84

Zone II (LISA) ■■■■■■ 3.12

Zone III (URBZ)■■■■■■■■ 3.65

Simpson's Evenness (E)

Zone I (CIA) ■■■■ 0.48

Zone II (LISA) ■■■■■■■ 0.79

Zone III (URBZ)■■■■■■■■■ 0.88

Table 2: Mathematical Summary of Alpha Diversity Across Investigated Sites

| Richness & Diversity Parameters | Zone I (CIA) | Zone II (LISA) | Zone III (URBZ) |
|---|---|---|---|
| Observed Species Richness (S) | 14 | 34 | 46 |
| Total Individuals Collected (N) | 212 | 442 | 594 |
| Shannon-Wiener Index (H') | 1.84 | 3.12 | 3.65 |
| Simpson’s Dominance Index (D) | 0.24 | 0.06 | 0.03 |

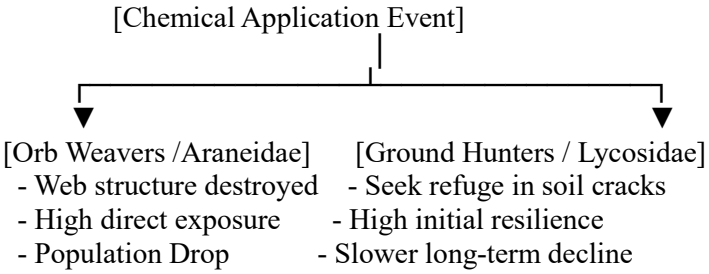
## 4. Discussion:

4.1 Spiders as Bioindicators of Pesticide Disturbance

The reduction in spider richness and abundance observed in Zone I (CIA) corresponds to patterns of heavy chemical usage documented in regional agricultural studies. Broad-spectrum synthetic insecticides suppress spider populations through acute mortality and chronic sublethal pathways, including reduced fecundity, disrupted web geometry, and disoriented hunting behaviors.

However, select species show varying tolerance thresholds. **Lycosidae** species maintain notable populations in disturbed cotton fields. Their cursorial, ground-dwelling habits allow them to

seek temporary refuge in soil cracks and surface debris, avoiding direct contact with foliar chemical sprays. In contrast, large web-builders depend on stable, intact crop canopies to support their webs. Frequent harvesting and chemical treatments disrupt these structures, causing them to abandon intensive conventional plots.




**5. Conclusion and Actionable Management Recommendations:**

This investigation confirms that spider assemblages serve as sensitive, functional bioindicators of environmental health and land management intensity within the agricultural landscapes surrounding Digras town. Simplified monoculture systems subjected to intensive chemical regimens support impoverished, unbalanced communities dominated by a few pesticide-tolerant ground runners. Conversely, low-input and natural buffer zones maintain diverse functional guilds that provide natural pest regulation.

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