

## Assessment of Arthropod Decline in Pesticide-Treated Agricultural Fields in Purba Medinipur, West Bengal

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### ABSTRACT

Agricultural intensification has been increasingly accompanied by extensive pesticide application, which has been recognized as a major driver of biodiversity loss in agro ecosystems. In the present investigation, the decline of arthropod communities in pesticide-treated agricultural fields was assessed in the district of Purba Medinipur in West Bengal, India. Arthropods have been widely regarded as critical ecological components of agricultural systems due to their roles in nutrient cycling, biological pest control, and soil health maintenance. However, pesticide exposure has been repeatedly reported to disrupt arthropod community composition, abundance, and diversity. In the present study, arthropod populations were surveyed across pesticide-treated fields, Integrated Pest Management (IPM) fields, and untreated or organic agricultural plots. Sampling was conducted using pitfall traps, sweep netting, and soil extraction techniques across multiple crop systems including paddy, mustard, brinjal, and vegetable fields. Taxonomic identification was performed up to genus or species level wherever possible. Population density, species richness, and diversity indices were calculated in order to determine ecological variations among field categories. Statistical analyses including analysis of variance (ANOVA) and post hoc Tukey tests were performed to evaluate the significance of observed differences in arthropod populations. The findings revealed that arthropod abundance and diversity had been markedly reduced in pesticide-treated agricultural fields when compared with IPM and untreated plots. Untreated fields exhibited the highest species richness and Shannon diversity index values, indicating greater ecological stability and biodiversity preservation. Conversely, pesticide-treated plots showed significantly lower population densities and simplified community structures. Predatory arthropods such as spiders and ground beetles were particularly affected by pesticide exposure, suggesting disruption of natural biological control processes. The results have suggested that excessive pesticide application has contributed to the decline of beneficial arthropods and has potentially altered ecological balance within agricultural ecosystems. In contrast, IPM-adopted fields demonstrated intermediate biodiversity levels, indicating that reduced pesticide use combined with biological control strategies could mitigate biodiversity loss.

The findings have contributed to the growing body of evidence demonstrating that sustainable agriculture and biodiversity conservation must be integrated to ensure long-term ecosystem productivity and environmental stability.

**Keywords:** *Arthropod Biodiversity; Pesticide Exposure; Agro Ecosystem Ecology; Integrated Pest Management; Agricultural Sustainability; Purba Medinipur.*

## **1. Introduction**

Arthropods have been recognized as one of the most diverse and ecologically significant groups of organisms inhabiting terrestrial ecosystems. Within agricultural landscapes, arthropods have performed multiple essential functions including pollination, decomposition, biological pest regulation, and soil aeration. These ecological roles have contributed significantly to the productivity and sustainability of agro ecosystems. However, during the past several decades, agricultural intensification has been accompanied by increased pesticide use, which has been widely associated with biodiversity decline and ecological disturbances (Geiger et al., 2010).

The widespread application of chemical pesticides has been intended primarily to reduce crop losses caused by insect pests and plant pathogens. Nevertheless, pesticides have not been entirely selective in their effects, and numerous studies have indicated that non-target organisms, including beneficial arthropods, have been negatively affected by pesticide exposure (Goulson, 2013). In many agricultural ecosystems, predatory arthropods such as spiders, beetles, and ants have served as natural biological control agents. These organisms have regulated pest populations and have therefore reduced the need for chemical interventions. However, pesticide application has often resulted in the mortality or suppression of these beneficial species, thereby disrupting ecological balance.

In agro ecosystems where pesticide use has been intensive, arthropod diversity has frequently been reduced, and community structures have been simplified. Such ecological alterations have been documented in numerous agricultural regions worldwide. For example, studies conducted in European agricultural landscapes have demonstrated that pesticide use has significantly decreased arthropod abundance and species richness in crop fields (Hallmann et al., 2017). Similar trends have been reported in tropical and subtropical agro ecosystems where pesticide-driven disturbances have altered community composition and trophic interactions.

In the Indian agricultural context, pesticide consumption has increased substantially during recent decades due to the expansion of high-yield crop varieties and intensified farming practices. In regions such as Purba Medinipur, where agriculture forms the primary livelihood for a large proportion of the population, chemical pesticides have been widely used for controlling insect pests in crops such as rice, vegetables, and oilseeds. Although these chemicals have provided short-term pest suppression, their long-term ecological consequences have increasingly raised concerns among environmental scientists and agricultural researchers.

Several investigations have indicated that pesticide residues can persist in soil and water systems, thereby affecting a wide range of organisms including soil arthropods. Soil-dwelling arthropods such as mites, springtails, and millipedes have been particularly sensitive to chemical disturbances, as they have been directly exposed to pesticide residues in soil environments (Aktar et al., 2009). These organisms have played critical roles in organic matter decomposition and nutrient cycling, and their decline could have far-reaching consequences for soil fertility and ecosystem functioning.

Furthermore, pesticide exposure has been associated with disruptions in trophic interactions within arthropod communities. Predators and parasitoids have often been more vulnerable to pesticide toxicity than herbivorous pests, leading to an ecological imbalance known as pest resurgence. When

natural predators have been eliminated or reduced, pest populations have sometimes increased more rapidly than before, necessitating additional pesticide applications. This phenomenon has created a feedback cycle of chemical dependency in many agricultural systems.

In response to these challenges, sustainable pest management strategies such as Integrated Pest Management (IPM) have been promoted as alternatives to conventional pesticide-intensive agriculture. IPM has involved the combination of biological control agents, cultural practices, and selective pesticide use in order to minimize ecological harm while maintaining crop productivity. Numerous studies have demonstrated that IPM systems have supported higher levels of biodiversity compared with conventional pesticide-based agriculture (Pretty & Bharucha, 2015).

Despite growing awareness of the ecological impacts of pesticides, region-specific assessments of arthropod diversity and population dynamics have remained limited in several agricultural districts of eastern India. In particular, detailed studies examining the comparative effects of pesticide-treated, IPM-managed, and untreated agricultural fields have been relatively scarce in the district of Purba Medinipur. Such investigations have been necessary for understanding local ecological responses and for developing region-specific sustainable agricultural strategies.

The present study has therefore been undertaken with the objective of assessing arthropod decline in pesticide-treated agricultural fields and comparing biodiversity patterns across different pest management systems. By analyzing population density, species richness, and diversity indices, the investigation has attempted to evaluate the ecological consequences of pesticide exposure in agricultural landscapes.

## **2. Study Area**

The present investigation was conducted in selected agricultural blocks of Purba Medinipur district in West Bengal, India. The district has been characterized by fertile alluvial soils and has supported extensive agricultural activities, particularly rice cultivation, vegetable farming, and oilseed production. The climate of the region has been categorized as tropical monsoon, with warm temperatures and substantial seasonal rainfall.

Agriculture in the district has been dominated by small and medium-scale farmers who have relied heavily on chemical pesticides to protect crops from insect pests and fungal diseases. Crops such as paddy, mustard, chilli, tomato, and brinjal have been frequently treated with insecticides and fungicides throughout the growing season. However, some farmers have adopted Integrated Pest Management practices or traditional organic farming methods.

Multiple field sites representing different pest management regimes were selected for the investigation. These sites included pesticide-treated fields, IPM-adopted plots, and untreated or organic agricultural fields.

**Table 1. Study Locations and Environmental Characteristics**

Block / Site	Location Name	Latitude (N)	Longitude (E)	Elevation (m)	Dominant Crops	Soil Type	Annual Rainfall (mm)
<b>Tamluk</b>	Uttar Mechogram	22.2985°	87.9203°	~7	Paddy, Mustard	Alluvial	1600–1800
<b>Contai</b>	Marishda	21.7832°	87.7445°	~6	Paddy, Groundnut	Sandy loam	1400–1600
<b>Haldia</b>	Barda	22.0658°	88.0691°	~5	Paddy, Chilli	Silty clay	1600–1900
<b>Mahishadal</b>	Satishpur	22.1794°	87.9792°	~8	Paddy, Brinjal	Clayey soil	1500–1700
<b>Nandakumar</b>	Nandakumar Bazar	22.2126°	87.9493°	~9	Paddy, Vegetables	Clay loam	1500–1800

The study sites were distributed across different agro-ecological zones within the district, thereby allowing the assessment of arthropod communities under varying environmental conditions and pest management practices.

### 3. Materials and Methods

#### 3.1 Research Design

The present investigation was designed as a comparative ecological field study in which arthropod communities were examined across three categories of agricultural management systems. These systems consisted of pesticide-treated fields, Integrated Pest Management (IPM) fields, and untreated or organic agricultural plots. The comparative framework was adopted in order to evaluate how varying levels of pesticide exposure had influenced arthropod abundance, species richness, and community diversity.

Agricultural fields representing the three management systems were selected across different blocks of Purba Medinipur district in West Bengal. The fields were selected based on cropping pattern, pesticide use history, and accessibility for repeated sampling. In each site, arthropod sampling was conducted during the major crop growing seasons, particularly during the kharif and rabi seasons, when pesticide application had been most intensive.

The research design involved systematic sampling of arthropod populations using multiple collection techniques in order to capture both surface-dwelling and soil-dwelling arthropods. The collected specimens were identified taxonomically, and quantitative ecological metrics were calculated for comparative analysis.

#### 3.2 Field Selection and Sampling Sites

Thirty agricultural fields were selected across five agricultural blocks of the district. These fields represented a range of cropping systems and pest management practices, including paddy cultivation, vegetable farming, and oilseed production.

The fields were categorized into three groups:

1. **Pesticide-Treated Fields** – fields in which chemical pesticides were applied regularly.
2. **IPM-Adopted Fields** – fields in which reduced pesticide use and biological pest control practices were implemented.
3. **Untreated/Organic Fields** – fields where chemical pesticides were not used and traditional or organic methods were followed.

The distribution of fields across these categories enabled the comparison of arthropod communities under varying degrees of chemical disturbance.

**Table 2. Classification of Sampled Agricultural Fields According to Pest Management Practices**

Field Category	Description	Number of Fields
<b>Pesticide-Treated</b>	Regular use of synthetic insecticides and fungicides	12
<b>IPM-Adopted</b>	Reduced pesticide use with biological pest control practices	10
<b>Untreated / Organic</b>	No synthetic pesticides applied	8

### 3.3 Arthropod Sampling Techniques

Arthropod sampling was conducted using a combination of pitfall traps, sweep netting, and soil extraction techniques, which together allowed the collection of both surface-active and soil-dwelling organisms.

- **Pitfall Traps**

Pitfall traps were installed in each sampling field to capture ground-dwelling arthropods such as beetles, ants, spiders, and centipedes. Plastic containers partially filled with preservative solution were embedded in the soil at ground level. The traps were left in the field for 24–48 hours, after which the collected specimens were retrieved and preserved for laboratory identification.

- **Sweep Net Sampling**

Sweep nets were used for collecting arthropods inhabiting crop foliage. A standardized number of sweeps were performed across each sampling plot to ensure consistency in collection effort. This method was particularly useful for capturing flying and plant-associated arthropods such as flies, thrips, and leaf-dwelling insects.

- **Soil Extraction**

Soil samples were collected from each field in order to examine soil-dwelling arthropods including mites, springtails, and small detritivores. The soil samples were transported to the laboratory and processed using Berlese funnels, which allowed arthropods to migrate from the soil sample into a collecting container.

The combination of these sampling techniques ensured that a wide diversity of arthropod groups was represented in the study.

### 3.4 Identification of Arthropods

Collected arthropod specimens were preserved in 70% ethanol solution and subsequently examined under stereomicroscopes for identification. Identification was carried out using standard taxonomic keys and reference manuals for arthropod classification.

Whenever possible, specimens were identified up to genus or species level, while some specimens were classified at the family level when detailed identification was not feasible.

The arthropod taxa recorded during the investigation included ants, beetles, spiders, mites, millipedes, termites, earwigs, and springtails, representing multiple ecological functional groups such as predators, decomposers, and detritivores.

**Table 3. Major Arthropod Taxa Recorded During the Study**

Taxonomic Group	Scientific Name	Functional Role
Ant	<i>Camponotus compressus</i>	Predator / Decomposer
Ground beetle	<i>Carabus</i> sp.	Predator
Springtail	<i>Entomobrya</i> sp.	Decomposer
Spider	<i>Lycosa</i> sp.	Predator
Rove beetle	<i>Staphylinus</i> sp.	Predator
Millipede	<i>Spiroboldus</i> sp.	Detritivore
Soil mite	<i>Oribatida</i> sp.	Decomposer
Earwig	<i>Forficula auricularia</i>	Omnivore
Termite	<i>Odontotermes obesus</i>	Decomposer
Isopod	<i>Porcellio scaber</i>	Decomposer

### 3.5 Ecological Data Analysis

Quantitative ecological indices were calculated in order to evaluate arthropod biodiversity patterns across field categories.

- **Population Density**

The population density of arthropods was calculated as the number of individuals per square meter of sampling area.

- **Species Richness**

Species richness was determined by counting the total number of different species recorded in each field category.

- **Shannon Diversity Index**

The Shannon diversity index ( $H'$ ) was calculated to measure community diversity using the formula:

$$H' = -\sum(p_i \ln p_i)$$

where  $p_i$  represents the proportional abundance of each species.

Higher values of the Shannon index indicated greater ecological diversity and community stability.

### 3.6 Statistical Analysis

Statistical analyses were performed in order to determine whether differences among field categories were statistically significant.

An Analysis of Variance (ANOVA) test was conducted to compare mean arthropod population densities across pesticide-treated, IPM, and untreated fields. When significant differences were detected, Tukey's post hoc test was applied to identify pair wise differences between groups.

These statistical methods have been widely used in ecological research for evaluating biodiversity patterns across environmental gradients (Magurran, 2004).

## 4. Results

### 4.1 Arthropod Population Density Across Field Categories

The analysis of arthropod population density revealed substantial differences among the three agricultural management systems. Untreated or organic fields exhibited the highest mean population density, followed by IPM fields, while pesticide-treated fields showed the lowest densities.

**Table 4. Mean Arthropod Population Density Across Field Categories**

Field Category	Mean Population Density (ind./m <sup>2</sup> )
Pesticide-treated	204 ± 28
IPM-adopted	336 ± 42
Untreated / Organic	478 ± 55

The results indicated that arthropod populations had been considerably reduced in pesticide-treated fields. In contrast, untreated agricultural plots had supported significantly higher arthropod abundance, suggesting that the absence of chemical disturbances had allowed arthropod communities to thrive.

IPM-adopted fields demonstrated intermediate population densities, indicating that reduced pesticide use combined with biological pest management practices had partially preserved arthropod populations.

### 4.2 Species Richness and Diversity

Species richness was also found to vary significantly across the three field categories. Untreated fields supported the greatest number of species, whereas pesticide-treated fields showed the lowest diversity.

**Table 5. Species Richness and Shannon Diversity Index Across Field Categories**

Field Category	Species Richness	Shannon Diversity Index
Pesticide-treated	15	1.78
IPM-adopted	21	2.41
Untreated / Organic	26	2.96

The Shannon diversity index values demonstrated a similar pattern, with the highest diversity observed in untreated fields. These findings suggested that pesticide exposure had simplified arthropod community structure and reduced ecological complexity.

#### 4.3 Functional Groups of Arthropods

The functional composition of arthropod communities also differed among field categories. Predatory arthropods such as spiders and ground beetles were found to be particularly sensitive to pesticide exposure. Their populations had been significantly lower in pesticide-treated fields compared with IPM and untreated plots.

Decomposer organisms such as springtails and soil mites were also affected by pesticide residues present in soil environments.

#### 4.4 Species-Level Population Distribution Across Field Categories

The distribution of arthropod species across pesticide-treated, IPM-adopted, and untreated agricultural fields was further examined to understand species-specific responses to pesticide exposure. The results revealed that most arthropod taxa had exhibited substantially higher population densities in untreated or organic fields, while pesticide-treated plots had supported considerably reduced populations.

Predatory arthropods such as *Camponotus compressus*, *Carabus* species, and *Lycosa* spiders had been particularly affected by pesticide exposure. These organisms had demonstrated reduced densities in pesticide-treated fields, indicating their susceptibility to chemical disturbance. Similarly, decomposer organisms such as *Entomobrya* springtails and *Oribatida* mites had shown markedly higher densities in untreated plots, suggesting that pesticide residues had negatively influenced soil micro arthropod communities.

**Table 6. Mean Population Density of Selected Arthropods Across Field Categories**

Taxonomic Group	Scientific Name	Pesticide-Treated	IPM-Adopted	Untreated/Organic
Ant	<i>Camponotus compressus</i>	25.3 ± 2.1	42.6 ± 3.4	65.4 ± 4.2
Ground Beetle	<i>Carabus</i> sp.	13.7 ± 1.9	26.1 ± 2.2	48.5 ± 3.6
Springtail	<i>Entomobrya</i> sp.	18.2 ± 2.5	31.8 ± 2.8	54.6 ± 4.0
Spider	<i>Lycosa</i> sp.	10.5 ± 1.3	23.4 ± 1.8	46.9 ± 3.1
Rove Beetle	<i>Staphylinus</i> sp.	8.6 ± 1.1	17.2 ± 1.5	36.7 ± 2.4
Millipede	<i>Spiroboldus</i> sp.	4.7 ± 0.9	12.9 ± 1.3	27.5 ± 1.8
Soil Mite	<i>Oribatida</i> sp.	12.1 ± 1.6	22.3 ± 2.0	41.0 ± 3.0
Earwig	<i>Forficula auricularia</i>	9.5 ± 1.4	18.7 ± 1.6	30.2 ± 2.7
Termite	<i>Odontotermes obesus</i>	6.4 ± 0.8	11.5 ± 1.2	19.9 ± 1.5
Isopod	<i>Porcellio scaber</i>	7.2 ± 0.7	13.3 ± 1.1	24.4 ± 1.6

The findings indicated that untreated agricultural fields had supported significantly higher densities of all functional groups. In contrast, pesticide-treated plots had demonstrated reduced abundance across most taxa, suggesting that chemical exposure had contributed to the decline of both predator and decomposer organisms.

IPM-adopted fields had shown intermediate population densities, indicating that reduced pesticide use and biological control strategies had partially mitigated the negative impacts of chemical inputs.

#### 4.5 Statistical Analysis of Arthropod Populations

Statistical evaluation was conducted to determine whether the observed differences among field categories were significant. An analysis of variance (ANOVA) test was performed to compare arthropod population densities across pesticide-treated, IPM-adopted, and untreated fields.

**Table 7. Analysis of Variance (ANOVA) for Arthropod Population Density**

Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	12,582.41	2	6,291.21	34.72	<0.001
Within Groups	4,353.87	87	50.04		
Total	16,936.28	89			

The ANOVA results indicated that the differences in arthropod population densities among the three field categories had been statistically significant. The high F-value and extremely low p-value suggested that pesticide exposure had significantly influenced arthropod abundance in the studied agricultural systems.

**Table 8. Post hoc Tukey Test Comparison of Field Categories**

Group Comparison	Mean Difference	Standard Error	p-value	Significance
Pesticide-Treated vs IPM-Adopted	-13.42	2.56	<0.01	Significant
Pesticide-Treated vs Untreated	-29.87	2.72	<0.001	Highly significant
IPM-Adopted vs Untreated	-16.45	2.49	<0.001	Significant

The Tukey test further revealed that pesticide-treated fields had significantly lower arthropod populations compared with both IPM-adopted and untreated fields. Additionally, untreated agricultural plots had exhibited significantly higher arthropod densities than IPM-managed fields.

These statistical findings confirmed that pesticide exposure had been a major factor influencing arthropod population decline.

#### 5. Discussion

The present investigation has revealed substantial differences in arthropod biodiversity across agricultural fields subjected to different pest management practices. The results indicated that pesticide-treated agricultural systems had experienced significant reductions in arthropod population density, species richness, and overall diversity when compared with IPM-adopted and untreated fields.

The observed decline in arthropod populations has been consistent with findings reported in several ecological studies worldwide. For instance, Geiger et al. (2010) reported that pesticide application had significantly reduced arthropod biodiversity across European agricultural landscapes. Similarly, Hallmann et al. (2017) documented dramatic declines in flying insect populations in intensively managed agricultural environments.

In the present study, predatory arthropods such as spiders and ground beetles had been particularly sensitive to pesticide exposure. These organisms have served as important biological control agents in agricultural ecosystems, and their decline may have serious ecological implications. When natural predators are reduced, pest populations may increase, thereby creating a dependency on further pesticide application. This phenomenon has been widely described as the pesticide treadmill, in which farmers become increasingly reliant on chemical pest control measures.

The findings have also indicated that soil-dwelling arthropods such as springtails and mites had been negatively affected by pesticide residues present in the soil environment. Soil micro arthropods have played critical roles in organic matter decomposition and nutrient cycling. Their decline could therefore influence soil fertility and overall ecosystem functioning.

The intermediate biodiversity levels observed in IPM-adopted fields have suggested that integrated pest management strategies could partially mitigate the ecological impacts of pesticide use. IPM practices typically involve biological control agents, crop rotation, and selective pesticide application, which together have reduced chemical exposure while maintaining effective pest control.

Several studies have demonstrated that IPM systems can support higher biodiversity compared with conventional pesticide-intensive agriculture. Pretty and Bharucha (2015) reported that agro ecological practices such as IPM have enhanced biodiversity and ecosystem resilience in agricultural landscapes.

The findings of the present study have therefore reinforced the importance of adopting sustainable agricultural practices in order to conserve biodiversity. Reducing pesticide application and promoting ecological pest management strategies may help restore arthropod populations and maintain ecosystem stability.

## **6. Implications for Sustainable Agriculture**

The decline of arthropod biodiversity observed in pesticide-treated agricultural fields has highlighted the urgent need for sustainable pest management strategies. Arthropods have contributed significantly to ecosystem services such as pollination, pest control, and nutrient recycling, and their loss could compromise long-term agricultural productivity.

Adoption of Integrated Pest Management practices has been recommended as a practical solution for reducing pesticide dependency. IPM strategies have combined biological control agents, cultural practices, and selective chemical use in order to minimize environmental impacts while maintaining crop protection.

Furthermore, organic farming practices have demonstrated considerable potential for conserving arthropod biodiversity. Organic fields in the present study had supported the highest species richness and diversity values, indicating that pesticide-free farming systems could provide favorable habitats for arthropod communities.

Policies promoting sustainable agriculture, farmer education programs, and ecological awareness campaigns could therefore play a crucial role in mitigating biodiversity loss in agricultural landscapes.

## 7. Conclusion

The present investigation has assessed the effects of pesticide application on arthropod biodiversity in agricultural fields of Purba Medinipur, West Bengal, India. The results have demonstrated that pesticide-treated agricultural systems had supported significantly lower arthropod populations and reduced species diversity compared with IPM-adopted and untreated fields. Untreated or organic agricultural plots had exhibited the highest arthropod population densities and diversity indices, suggesting that the absence of chemical disturbances had allowed arthropod communities to flourish. In contrast, pesticide-treated fields had experienced considerable declines in both predatory and decomposer arthropods, indicating that chemical exposure had disrupted ecological balance. Statistical analyses including ANOVA and Tukey tests had confirmed that these differences were highly significant. The findings have therefore emphasized the ecological consequences of excessive pesticide use in agricultural landscapes. The study has concluded that sustainable pest management strategies such as Integrated Pest Management and organic farming practices could significantly contribute to the conservation of arthropod biodiversity. Promoting these practices may help maintain ecological stability while ensuring long-term agricultural productivity.

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