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Insights from Insect Diversity and Functional Roles in Sorghum Pest Management: A Case Study from Northern Sumatera, Indonesia

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Abstract

This study, conducted in Lalang Village, Tebing Tinggi, Indonesia, from August to October 2021, aimed to investigate the insect diversity and functional roles relevant to Sorghum *(Sorghum bicolor)* monoculture. Employing a purposive random sampling method, we utilized four trapping techniques (yellow sticky trap, pitfall trap, light trap, and sweep net) according to standard protocols. Analysis revealed insects recorded from *S. bicolor*, representing seven orders (Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Odonata, Orthoptera), 28 families, 32 species, totaling 10,022 individuals. We identified 32 species, classified into four insect functional groups: parasitoids (3 families), pollinator (1 family), predators (12 families), and pests (12 families). The Importance Value Index (IVI) values were compared among the functional groups, collectively indicating that *Apis mellifera* (Order Hymenoptera Family Apidae) was the most prevalent pollinator, followed by parasitoids comprising three families (Ichneumonidae, Ceraphronidae, and Tachinidae). Pest species, including *Agrotis ipsilon*, *Helicoverpa armigera*, *Mythimna separata*, *Eublemma silicula*, and *Spodoptera frugiperda*, exhibited the highest IVI value of 27.14%. Predators were led by *Podisus maculiventris* (Family Pentatomidae) with an IVI value of 9.19%. Pests dominated with an abundance of 62.09%, followed by predators (31.49%), pollinators (5.98%), and parasitoids (0.44%). The t-test results were significant across day after sowing (DAS) and different traps with scores such as t-day after sowing (t-DAS)=22.051; t-yellow sticky trap (t-YST)=12.311; t-pit fall trap (t-PFT)=10.271; t-light trap (t-LT)=12.403; t-sweep net (tSN)=12.99, where h<0.01). Biological indices indicated a low species richness (R1=2.11), high species evenness (E=0.824), and moderate Shannon-Wiener diversity score (H'=2.27). Understanding the functional roles of these insects in *S. bicolor* cultivation emphasizes the necessity of integrated pest management for effective pest control strategies. Our findings stress the importance of biodiversity conservation and effective management practices for sustainable sorghum cultivation in Northern Sumatera, Indonesia.

Keywords: integrated pest management, *Sorghum bicolor*, insect diversity, functional roles, Indonesia

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Sorghum [*Sorghum bicolor* (L.) Moench], a versatile cereal crop, holds significant promise for cultivation and development in marginal and arid areas regions of Indonesia. Its inherent advantages lie in its wide agroecological adaptability, drought tolerance (Wagaw, 2019), cost-effectiveness in cultivation, and robust resistance to pests and diseases (Anas, 2016). Among the several types of sorghum, sweet sorghum stands out as a particularly valuable variety, serving both as animal feed and a renewable energy source. Sweet sorghum boasts a high sugar content in its stalks, ranging from 76% to 78%, akin to sugarcane (68%-80%) (Balitsereal, 2012; Mishra et al., 2012). Many nations have long utilized sweet sorghum for ethanol production, animal feed, and various industrial applications (Ekefre, 2017; Phukoetphim, 2017).

Despite its potential, sorghum production in Indonesia has seen only marginal growth over the past few years, as indicated by data from cereal cultivation distributors in 2013, which shows an increase from 6,114 tons to 7,695 tons over 5 years (Indonesian Central Bureau of Statistical, 2021). Given Indonesia's substantial potential for sorghum development (Subagio & Aqil, 2013; 2014), increasing production requires concerted efforts. However, sorghum remains unfamiliar to many, with only a small portion of the population aware of its existence. Thus, there is a need to introduce sorghum to the public through processed food products (Riyanti & Nurngaini, 2016; Soeranto, 2016). Although sorghum flour has potential as an ingredient in food manufacturing in Indonesia, its utilization remains limited.

According to Prasad et al. (2021), at least 150 insects have been reported as pests of sorghum worldwide, of which the major ones are shoot fly *(Atherigona soccata)*, stem borer *(Chilo partellus)*, shoot bug *(Peregrinus maidis)*, aphids *(Melanaphis sacchari)*, sorghum midge *(Stenodiplosis sorghicola)*, head bug *(Calocoris angustatus)*, head caterpillars *(Helicoverpa, Eublemma, Pyroderces)* and spider mites *(Oligonychus* spp.*)*. The grain yields are low (500–800 kg/ha), mainly attributed to damage caused by these insect pests. It provides compiled information on pest bionomics, damage symptoms, and economic losses in sorghum due to pests. Various management strategies adopted, viz., cultural, biological, host plant resistance, use of botanicals, and chemical management, are detailed. Recent advances in pest management, viz., marker-assisted selection and transgenics, are also discussed and helpful in pest management. Meanwhile, *Atherigona soccata* attacks sorghum at the age of a week, while *Busseola fusca* attacks young leaves of sorghum, which are still curled. *Diatraea saccharalis* infests the shoots of young sorghum plants, *Phyllophaga* spp. attacks young roots of sorghum, *Nezara viridula* sucks on the panicles, *Chilo sacchariphagus* attacks sorghum 10-15 days after planting, and *Helicoverpa armigera* grows up on the ground.

Geographically, Tebing Tinggi offers a sample land area suitable for sorghum cultivation. Nonetheless, pest infestation poses a significant challenge to sorghum farmers, with various insect species attacking sorghum plants from early stages to just before harvest. This study aims to investigate the composition, species richness, diversity, and insect dominance across sorghum growth stages. Furthermore, the study explores the potential application of Integrated Pest Management (IPM), employing techniques such as yellow sticky traps, sweep nets, pitfall traps, and light traps to effectively manage pests on *S. bicolor* plantations.

Materials and Methods

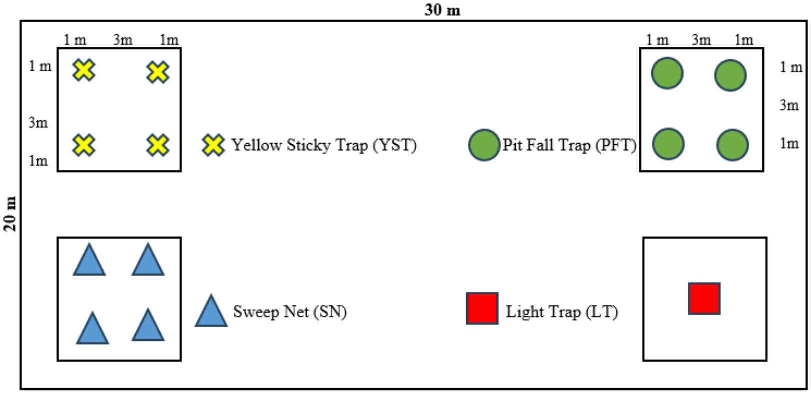
The research was conducted on rice farmers' land, covering an area of 800 square meters, situated at an elevation of 21 meters above sea level (masl) in Lalang Village, Rambutan District, Tebing Tinggi, spanning from July to October 2021. The study comprised several stages, including surveys, field research, laboratory-based pest identification, and analysis of insect data. Purposive sampling was employed to gather data on the monoculture sorghum variety Numbu. The materials used in the study included detergent, transparent plastic, yellow Asturo paper, adhesive glue, 70% ethanol solution, gauze, Yellow Sticky Trap (YST), Pit Fall Trap (FPT), Light Trap (LT), Sweep Net (SN), plastic cups, basins, masking tape, tweezers, scissors, sample bottles, syringe, loop, camera, stereo binocular microscope, and stationery. Insects were identified using reference materials (Firmansyah et al., 2012; Kalshoven, 1981). Yellow Sticky Trap (YST) and PFT were installed on the land at 4 points in a rectangle, then one LT using emergency light was used at night in the middle of planting, and SN was used to catch flying insects in sorghum plantation in 5 x 5 m. Insect captures were carried out starting from the vegetative period 20 days after germination until the seeds were physiologically mature. Trap installations were conducted at 08:00, and insect collection was carried out on the third day at 18:00, with 3 days of installation for each observation. The fieldwork involved setting up traps and conducting regular monitoring to collect insects.

Yellow Sticky Traps (YST) were constructed from 20 x 30 cm yellow paper and coated with adhesive. Four traps were deployed using wooden posts positioned within the sorghum canopy and adjusted according to the phase of plant growth. The strategic placement of these traps facilitated the attraction and subsequent entrapment of insects drawn to the vibrant color. These traps were set up in the morning at 08:00 and collected on the third day. Light traps were set at night starting at 18:00 and then taken at 06:00 the following day, once for each observation, while sweep nets were used to take samples of vegetation insects. This tool was made of light and durable material such as gauze, which is easy to swing, and the caught insects can be seen. Yellow Sticky Trap (YST) installation was carried out using a diagonal system with monitoring intervals of once every three days and a monitoring time of five times for two weeks. The arrests occurred between 07:00 and 09:00, followed by another round between 17:00 and 18:00. Subsequently, the captured insects were collected, separated, and placed into a sample bottle for identification in the laboratory.

Pit Fall Trap (PFT) installation was carried out according to the growth phase of the sorghum plantation, namely when the 5th leaf midrib was visible (20 Days After Sowing/DAS), growing point differentiation (30 DAS), flag leaf emergence (40 DAS), and flag leaf midrib inflated (50 DAS). Insects caught in the traps were taken, counted, and separated by type. The collected insects were carefully put into a sample bottle with a lid using tweezers. The sampling sites and installation of traps are described in Figure 1. Four Yellow Sticky Traps (YST) were placed at the corners of a 5 x 5-m rectangular planting area, like Pit Fall Traps (PFT) and Sweep Nets (SN). A single Light Trap (LT) was positioned in the center, utilizing an emergency light to attract nocturnal flying insects.

Figure 1

The Sampling Sites and Installed Traps



Upon collection, insect specimens were transported to the laboratory for further analysis. All insects were identified using appropriate taxonomic keys and reference materials. Subsequently, insect composition, abundance, and diversity data were analyzed using standard statistical methods (t-Test using SPSS version 24.00) and calculations of Biological Indices, i.e., Richness, Evenness, and Diversity Shannon-Wiener.

Biological Indices

Biodiversity is a function of the total number of taxa present, the evenness with which they are dispersed (either within species or within families), and the relationship between richness and evenness, or diversity (Ludwig & Reynolds, 1988). Insects, making up over 80% of Earth's described species diversity (Samways, 1993), are frequently used as ecological indicators. Several biological indices measure this diversity, including the Richness Index (S), Species Evenness (E), and the Shannon-Wiener Diversity Index (H'). The formulas for these indices are as follows:

a. Richness Index (S)
S= Total number of species in the sample (Pielou, 1984)

b. Species Evenness (E) (Ludwig & Reynolds, 1988)

$E = (H' / \ln(S))$

Where:
E: Represents the Species Evenness value.
H': Represents the Shannon-Wiener Diversity Index value.
ln(S): Natural logarithm (base-e) of the total number of species (S) in the sample.

c. Shannon-Wiener Diversity Index value (H') (Krebs, 1978)

$H' = - \Sigma (pi * \ln(pi))$

Where:
H': Represents the Shannon-Wiener Diversity Index value.
Σ: Sigma symbol, signifying summation.
pi: Represents the proportion of individuals belonging to species "i" in the total sample. Calculate this by dividing the number of individuals of species "i" by the total number of individuals in the sample (ni / N).
ln(pi): Natural logarithm (base-e) of pi.

Results and Discussion

Insect Diversity, Functional Roles, and Importance Value Index Analysis for Pest Management

The survey of insects in Sorghum *(S. bicolor)* crop field revealed representatives from seven orders (Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Odonata, Orthoptera), spanning 28 families (Acrididae, Alydidae, Apidae, Aphididae, Bibionidae, Ceraphronidae, Cecidomyiidae, Chironomidae, Chrysomelidae, Coccinellidae, Delphacidae, Dermestidae, Formicidae, Gerridae, Gryllidae, Ichneumonidae, Libellulidae, Muscidae, Noctuidae, Pentatomidae, Pompilidae, Pyralidae, Pyrrhocoridae, Reduviidae, Scarabidae, Sphecidae, Tachinidae, Vespidae), and 32 species totaling 10,022 individuals. Among the employed trapping techniques, the sweep net (SN) yielded the highest insect population count with 2,975 individuals, followed by the yellow sticky trap (YST) with 2,857 individuals, the light trap (LT) with 2,736 individuals, and the pitfall trap (PFT) with 1,454 individuals (Table 1). Our findings were lower than the sorghum study in Kolam, Percut Sei Tuan, which documented 1,173 individuals across 10 orders and 33 families (Parlindungan et al., 2020). The assumptions were influenced by supporting factors, including land suitability with a homogenous plantation (only sorghum area), limited food resources from moculture by sorghum, environmental factors (rainy season), quality of seeds is not non-uniform growth using ratoon, and soil type (Nisa et al., 2022), were effected of population insects in sorghum.

Table 1

The Sampling Sites and Installed Traps

DAS	Order	Family	Species	YST	PFT	LT	SN
20	Coleoptera	Coccinellidae	*Coccinela* sp.	5	3	5	3
	Coleoptera	Chrysomelidae	*Chaetocnema* sp.	13	15	20	24
	Coleoptera	Scarabidae	*Holotrichia consanguinea*	7	3	7	5
	Coleoptera	Dermestidae	***Trogoderma granarium***	**3**	**3**	**3**	**3**
	Diptera	Cecidomyiidae	*Stenodiplosis sorghicola*	14	0	17	35
	Diptera	Muscidae	*Atherigona soccata*	16	0	18	45
	Diptera	Tachinidae	*Tachina fera*	5	3	5	3
	Diptera	Bibionidae	*Bibio hortulanus*	7	3	7	3
	Diptera	Chironomidae	*Chironomus riparius*	5	3	5	3
	Hemiptera	Gerridae	***Limnogomus sp.***	**3**	**3**	**3**	**3**
	Hemiptera	Alydidae	*Riptortus linearis*	3	3	3	3
	Hemiptera	Reduviidae	*Sycanus annulicornis*	3	3	3	3
	Hemiptera	Pyrrhocoridae	*Disderkus cingulatus*	3	3	3	3
	Hemiptera	Aphididae	*Rhophalosiphum maidis*	18	19	21	22
	Hemiptera	Delphacidae	*Peregrinus maidis*	15	18	19	24
	Hemiptera	Pentatomidae	*Podisus maculiventris*	18	19	37	48
	Hymenoptera	Vespidae	*Vespa* sp.	3	3	3	3
	Hymenoptera	Sphecidae	*Chalybion* sp.	5	3	5	3
	Hymenoptera	Ichneumonidae	*Xanthopimpla punctata*	5	3	5	3
	Hymenoptera	Pompilidae	*Anoplius* sp.	3	3	3	3
	Hymenoptera	Ceraphronidae	*Ceraphron* sp.	3	3	3	3
	Hymenoptera	Formicidae	*Solenopsis Molesta*	3	3	3	3
	Hymenoptera	Apidae	*Apis mellifera*	38	15	38	41
	Lepidoptera	Noctuidae	*Agrostis ipsilon*	43	9	46	39
	Lepidoptera	Noctuidae	*Helicoverpa armigera*	42	0	50	37
	Lepidoptera	Pyralidae	*Chilo partellus*	31	8	45	49
	Odonata	Libellulidae	*Orthetrum sabina*	5	3	3	3
	Orthoptera	Acrididae	*Locusta migratoria*	3	3	3	3
	Orthoptera	Gryllidae	*Gryllus* sp.	3	3	3	3

Footnotes: DAS = Day After Sowing; YST = Yellow Sticky Trap; PFT = Pitfall Trap; LT=Light Trap; SN=Sweep Net; - =None.

DAS	Order	Family	Species	YST	PFT	LT	SN
30	Coleoptera	Chrysomelidae	*Chaetocnema* sp.	7	9	18	19
	Coleoptera	Scarabaeidae	*Holotrichia consanguinea*	11	0	10	28
	Diptera	Cecidomyiidae	*Contarinia sorghicola*	18	0	17	29
	Diptera	Cecidomyiidae	*Stenodiplosis sorghicola*	6	8	17	18
	Diptera	Muscidae	*Atherigona soccata*	5	14	18	19
	Hemiptera	Aphididae	*Rhophalosiphum maidis*	33	18	37	47
	Hemiptera	Delphacidae	*Peregrinus maidis*	41	16	33	43
	Hemiptera	Pentatomidae	*Podisus maculiventris*	44	19	39	40
	Hymenoptera	Apidae	*Apis mellifera*	41	0	45	48
	Lepidoptera	Noctuidae	*Helicoverpa armigera*	38	17	48	42
	Lepidoptera	Noctuidae	*Mythimna separata*	41	9	40	44
	Lepidotera	Pyralidae	*Chilo partellus*	46	12	15	12
40	Coleoptera	Chrysomelidae	*Chaetocnema* sp.	48	13	34	43
	Coleoptera	Scarabaeidae	*Holotrichia consanguinea*	38	17	48	47
	Diptera	Cecidomyiidae	*Contarinia sorghicola*	39	16	45	41
	Diptera	Cecidomyiidae	*Stenodiplosis sorghicola*	46	16	29	30
	Diptera	Muscidae	*Atherigona soccata*	67	12	40	30
	Hemiptera	Aphididae	*Melanaphis sorghi*	63	36	71	75
	Hemiptera	Delphacidae	*Peregrinus maidis*	78	46	87	73
	Hemiptera	Pentatomidae	*Podisus maculiventris*	68	48	79	69
	Hymenoptera	Apidae	*Apis mellifera*	75	38	76	80
	Lepidoptera	Noctuidae	*Eublemma silicule*	41	43	35	46
	Lepidoptera	Noctuidae	*Helicoverpa armigera*	75	47	74	78
	Lepidoptera	Noctuidae	*Mythimna separata*	43	45	32	31
	Lepidoptera	Pyralidae	*Chilo partellus*	46	41	78	85
	Lepidoptera	Pyralidae	*Cryptoblabes gnidiella*	43	46	38	32
50	Coleoptera	Chrysomelidae	*Chaetocnema* sp.	31	16	37	46
	Coleoptera	Scarabaeidae	*Holotrichia consanguinea*	43	10	39	48
	Diptera	Cecidomyiidae	*Contarinia sorghicola*	40	45	35	37
	Diptera	Cecidomyiidae	*Stenodiplosis sorghicola*	48	17	36	40
	Diptera	Muscidae	*Atherigona soccata*	78	15	38	37
	Hemiptera	Aphididae	*Melanaphis sorghi*	39	12	43	45
	Hemiptera	Delphacidae	*Peregrinus maidis*	48	0	0	41
	Hemiptera	Pentatomidae	*Podisus maculiventris*	47	17	43	45
	Hymenoptera	Apidae	*Apis mellifera*	0	14	48	2
	Lepidoptera	Noctuidae	*Agrostis ipsilon*	78	34	81	78

Footnotes: DAS = Day After Sowing; YST = Yellow Sticky Trap; PFT = Pitfall Trap; LT=Light Trap; SN=Sweep Net; - =None.

DAS	Order	Family	Species	YST	PFT	LT	SN
	Lepidoptera	Noctuidae	*Eublemma silicule*	68	48	83	88
	Lepidoptera	Noctuidae	*Helicoverpa armigera*	75	34	37	76
	Lepidoptera	Noctuidae	*Mythimna separata*	79	34	32	65
	Lepidoptera	Noctuidae	*Spodoptera frugiperda*	67	46	77	73
	Lepidoptera	Pyralidae	*Chilo partellus*	45	47	34	46
	Lepidoptera	Pyralidae	*Cryptoblabes gnidiella*	78	34	30	85
	Lepidoptera	Pyralidae	*Marasmia trapezalis*	43	48	35	32
60	Coleoptera	Chrysomelidae	*Chaetocnema* sp.	36	33	75	81
	Coleoptera	Scarabaeidae	*Holotrichia consanguinea*	32	30	44	43
	Diptera	Cecidomyiidae	*Contarinia sorghicola*	43	10	34	36
	Diptera	Cecidomyiidae	*Stenodiplosis sorghicola*	38	16	41	45
	Diptera	Muscidae	*Atherigona soccata*	86	16	37	43
	Hemiptera	Aphididae	*Melanaphis sorghi*	66	35	56	58
	Hemiptera	Delphacidae	*Peregrinus maidis*	78	38	78	67
	Hemiptera	Pentatomidae	*Podisus maculiventris*	67	16	78	80
	Lepidoptera	Noctuidae	*Agrostis ipsilon*	78	43	76	68
Total				**2,857**	**1,454**	**2,736**	**2,975**

The number of insects captured varied among the four traps, with SN and YST showing the highest diversity, likely due to the attraction of active flyers in *S. bicolor* fields, supported by Mas'ud's (2011) findings on the effectiveness of YST. At 20 days after sowing (DAS), the sorghum midge *(Stenodiplosis sorghicola)* was found in three out of four traps, with 14 individuals captured by the YST, 17 by the LT, and 35 by the SN. Subsequently, at 30, 40, 50, and 60 DAS, all four traps successfully captured them (Table 1). This species is recognized as the most widespread and significant pest of *S. bicolor* globally and is the sole midge species known to infest *S. bicolor* crops (Young & Teetes, 1977). The Acrididae and Gryliidae were the lowest families recorded from 20 DAS, possibly due to their colonial nature and abundant food sources (Wagaw, 2019; Sidabutar, 2016), followed by the Gerridae family showed the lowest population, indicating a preference for other resources such as flowers, nectar, and more attractive aromas than those from *S. bicolor* plants. According to Harris-Shultz et al. (2022), aphids (Hemipteran) were recorded as significantly more diverse than ants, braconid wasps, diapriid, encyrtid, halictid bees, mymarid, scelionid wasps, and sphecid, with slightly lower recordings from pompilids or mutillids.

Table 2 shows the results of the t-test, indicating significant differences from days after sowing (DAS) and the variance of traps with scores, such as insects collected from day after sowing, t-DAS=22.051; insect trapping by yellow sticky trap, t-YST=12.311; insects trapping by pitfall trap, t-PFT=10.271; insects trapping by light trap, t-LT=12.403; and insect trapping by sweep net, t-SN=12.99, where h<0.01.

Table 2

One Sample T-test Analysis for Comparison of Insect Collection Efficiency Using Different Traps

Treatments	t	dF	Sign. (2 tailed)	Mean Difference
Day after Sowing (DAS)	22.051	79	*<.001*	35.50000
Yellow Sticky Trap (YST)	12.311	79	*<.001*	35.71250
Pit Fall Trap (PFT)	10.271	79	*<.001*	18.17500
Light Trap (LT)	12.403	79	***<.001***	**34.20000**
Sweep Net (SN)	12.99	79	*<.001*	37.18750

As depicted in the data, organisms exhibiting a high Importance Value Index (IVI) play pivotal roles in community dynamics, often leading to dominance among species (Table 3). IVI serves to quantify the degree of control a species exerts over its community. The insects were classified into four functional groups: parasitoids, pollinators, predators, and pests.

In the pest category, five species, such as *Agrostis ipsilon*, *Eublemma silicule*, *Helicoverpa armigera*, *Mythimna separata*, *Spodoptera frugiperda* (Order Lepidoptera, Family Noctuidae) recorded the highest IVI percentage at 27.14% (2720 individuals), followed by pollinator, *Apis mellifera* (Hymenoptera, Apidae), three parasitoid families (Ichneumonidae, Tachinidae, and Ceraphronidae) with lower values of 0.44%, each represented by 16, 16, and 12 individuals, respectively. Then *Podisus maculiventris* (Hemiptera: Pentatomidae) showed a predator attacking the sorghum field. Aditama and Kurniawan (2013) posit that high IVI values are influenced by organisms' reproductive and adaptive abilities to environmental conditions. Implementing strategies such as resistant varieties, plant extracts, pheromones, and minimal chemical usage in an integrated pest management system in *S. bicolor* Numbu fields can enhance sustainability. Additionally, *S. bicolor* holds promise as a future food source in Asia (Susilowatii & Saliem, 2013). Insects with the potential to become pests, including *Agrotis ipsilon*, *Helicoverpa armigera*, *Mythimna separata*, *Eublemma silicula*, and *Spodoptera frugiperda* (Family Noctuidae), exhibited the highest IVI value of 27.14% (2720 individuals), while lower values were calculated for five families (Family Acrididae, Family Alydidae, Family Dermestidae, Family Pompilidae, and Family Pyrrhocoridae). In the predator categories, *Podisus maculiventris* (Family Pentatomidae) recorded 9.19% (921 individuals), whereas Family Formicidae, Family Gerridae, Family Gryllidae, Family Reduviidae, and Family Vespidae had 12 individuals each (Table 3). Percentages of IVI serve to delineate the critical role of a species within the ecosystem. Borror et al. (1992) suggest that species with the highest IVI tend to dominate their habitat due to environmental suitability. These findings align with Aditama and Kurniawan's (2013) assertion that high IVI values are influenced by organisms' reproductive and adaptive capacities to environmental conditions.

Table 3

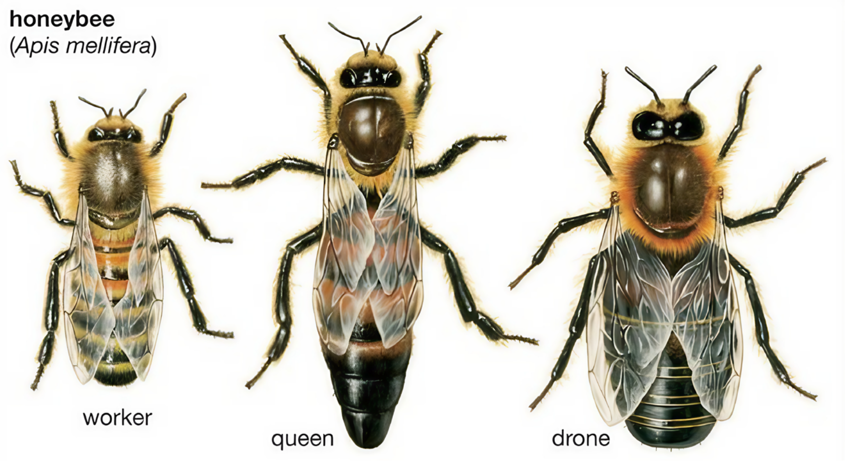
Importance Value Index (IVI) and Functional Status of Insects in Sorghum (S. bicolor) Plantations

Classification		Functional Status	Total (% IVI)
Order	**Family**		
Coleoptera	Coccinellidae	Predator	15 (0.15)
	Chrysomelidae	Pest	591 (5.89)
	Scarabidae	Predator	510 (5.09)
	Dermestidae	Pest	**12 (0.12)**
Diptera	Cecidomyiidae	Pest	1002 (10.20)
	Muscidae	Pest	634 (6.33)
	Tachinidae	Parasitoid	16 (0.16)
	Bibionidae	Predator	20 (0.20)
	Chironomidae	Predator	16 (0.16)
Hemiptera	Alydidae	Pest	12 (0.12)
	Aphididae	Pest	215 (2.15)
	Delphacidae	Pest	905 (9.03)
	Gerridae	Predator	12 (0.12)
	Pentatomidae	Predator	921(9.19)
	Pyrrhocoridae	Pest	12 (0.12)
	Reduviidae	Predator	12 (0.12)
Hymenoptera	Vespidae	Predator	12 (0.12)
	Spechidae	Predator	16 (0.16)
	Ichneumonidae	Parasitoid	16 (0.16)
	Pompilidae	Pest	12 (0.12)
	Ceraphronidae	Parasitoid	12 (0.12)
	Formicidae	Predator	12 (0.12)
	Apidae	Pollinator	599 (5.98)
Lepidoptera	Noctuidae	Pest	2720 (27.14)
	Crambidae	Pest	730 (7.29)
Odonata	Libellulidae	Predator	14 (0.14)
Orthoptera	Acrididae	Pest	12 (0.12)
	Gryllidae	Predator	12 (0.12)

Based on the status and function of insects divided into four categories based on functional group of insects— parasitoids, pollinators, predators, and pests, it highlighted typically diverse species of insects based on status and functional insect grouping (Figure 1). Among these categorized pests exhibited the highest abundances (6,223 individuals; 62.09%), followed by predators (3,156 individuals; 31.49%) and pollinators (599 individuals; 5.98%), with the lowest being parasitoids (44 individuals; 0.44%) (Figure 2). High values indicate dominance and superior adaptability compared to other species in the environment. These values are influenced by several factors, including the species' ability to survive and adapt to their habitat and their utilization of existing resources.

Figure 2

Apis mellifera (Source: Encyclopaedia Britannica, Inc, 2012)

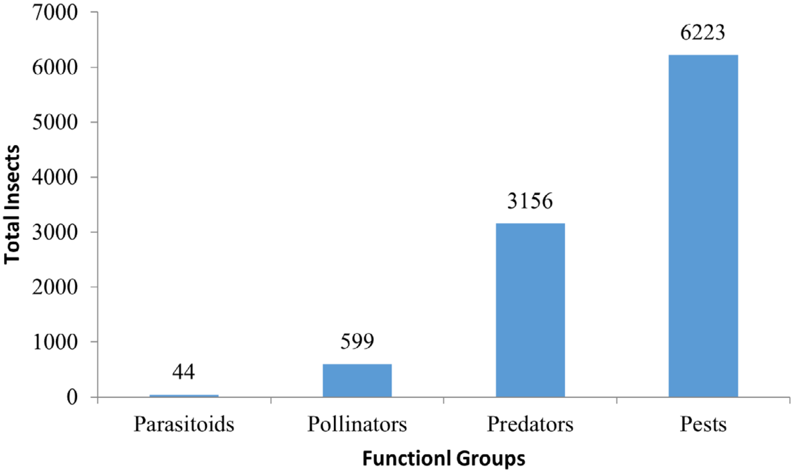


Categories of Functional Status of Insects around Ratoon Sorghum *(S. bicolor)* Flowers

During the sampling time, insects were collected separately in four categories based on functional status, such as parasitoid (44 individuals), pollinator *Apis mellifera* (Hymenoptera: Apidae, 599 individuals, Figure 2), predator (3,156 individuals), and pest (6,223 individuals) (Figure 3). This dominance of the Apidae family reflects its role as a primary pollinator, consistent with findings by Aminah et al. (2020), who highlighted several pollinator families from the orders Hymenoptera (Apidae), such as *Apis mellifera* and *Apis cerana*. In contrast, the lowest count of pollinator insects was from the Pieridae family (Lepidoptera) but not recorded in our study sites. The high mobility behavior of the Family Apidae may contribute to the lower individual count observed in ratoon sorghum fields in Lalang village, Tebing Tinggi, North Sumatra. Among the pollinators, the order Hymenoptera is dominated by the honeybee *(Apis mellifera)*, renowned for its high productivity and adaptability. The honeybee, a social insect, forms colonies comprising queen, male, and worker bees, providing numerous benefits to human beings. According to Siregar et al. (2022), *A. mellifera* was observed to possess the highest population, demonstrating an elevated level of productivity and easy adaptability to new environments.

Figure 3

Total Number of Insects across Various Functional Groups

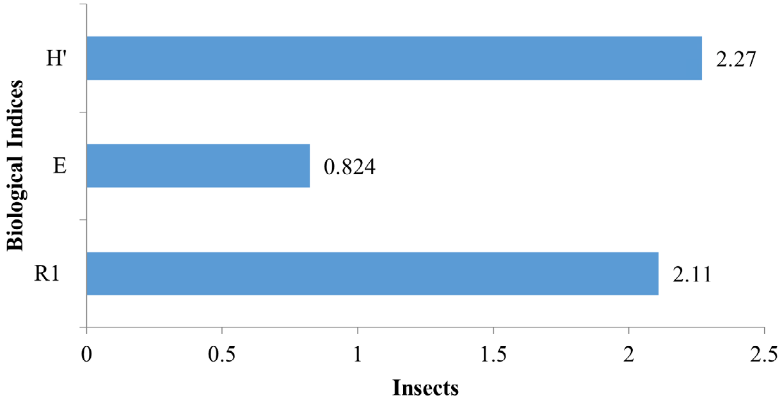


Biodiversity Analysis in Ratoon Sorghum *(S. bicolor)* Fields

The biological calculation results are presented in Figure 4. The species richness index (RI) within the ratoon sorghum *(S. bicolor)* planting area is 2.11, indicating a low level of species richness according to Margalef's criteria (1958), where RI < 2.5 signifies low richness. This index value reflects the number of species present in the community and is influenced by the total number of individuals observed in the *S. bicolor* planting area. Krebs (1978) observed that communities with a greater number of species have higher richness indices.

Figure 4

Measurement of Biological Indices (H', E, and R1)



Species evenness, which considers species diversity and relative abundance, is crucial for understanding community dynamics. The Evenness Index (E) provides insights into how individuals are distributed among species within a community. In ratoon sorghum plantations, the Evenness Index (E) value of 0.824 indicates a high level of evenness, suggesting a balanced distribution of species, with values closer to 1 indicating greater balance. This finding is consistent with research by Hanafi (2021), associating higher evenness index values with areas hosting abundant species diversity. The obtained value classifies the species evenness index as high (Mawazin & Subiakto, 2013). Similarly, the species Evenness Index, at 0.824 (classified as high category), reinforces the notion of a balanced species distribution. Oka (2005) classified evenness index values into three categories: E' <0.3 (low), 0.3>E'>0.6 (medium), and E'>0.6 (high). Haneda et al. (2013) and Tahihoran et al. (2020) further emphasize that higher evenness values indicate a more balanced distribution pattern within a community. According to Oka (1995), higher evenness values occur when no single family dominates the population, while lower values are associated with one family dominating others. Our analysis of species evenness revealed a high level of evenness, indicating a balanced species distribution within the community. The species richness index further corroborated this, suggesting a low level of species richness. The Shannon-Weiner diversity index (H') is 2.27, indicating moderate diversity, like a similar finding by Siregar et al. (2022), where H' in *S. bicolor* recorded was 2.13 using by sweep net (SN) and 2.56 by yellow sticky trap (YST).

Conclusion

Our study on Sorghum *(S. bicolor)* revealed a rich diversity of insects comprising seven orders, 28 families, and 32 species, totaling 10,022 individuals. These insects were categorized into four functional groups: parasitoids (3 families), pollinators (1 family), predators (12 families), and pests (12 families). The Importance Value Index (IVI) indicated *Apis mellifera* (Order Hymenoptera, Family Apidae) as the most prevalent pollinator, followed by parasitoids comprising three families (Ichneumonidae, Ceraphronidae, and Tachinidae). Pest species, including *Agrotis ipsilon*, *Helicoverpa armigera*, *Mythimna separata*, *Eublemma silicula*, *Spodoptera frugiperda* exhibited the highest IVI value of 27.14%. Predatory insects, particularly *Podisus maculiventris* (9.19%), exhibited significant abundance. Pests dominated with 62.09% abundance, followed by predators (31.49%), pollinators (5.98%), and parasitoids (0.44%). Among the functional categories, pests were the most abundant, highlighting their potential impacts on *S. bicolor* cultivation. Conversely, pollinators and parasitoids were relatively low in abundance, emphasizing the need for conservation efforts to support ecosystem balance. Biological indices indicated a low species richness (RI = 2.11), high species evenness (E = 0.824), and moderate Shannon-Wiener diversity score (H' = 2.27). The t-test results showed significant differences in insects collected from the day after sowing (DAS) and variance of traps with scores such as t-DAS=22.051; t-YST=12.311; t-PFT=10.271; t-LT=12.403; t-SN=12.99, where h<0.01).

Notably, the prevalence of honeybees *(Apis mellifera)* underscores their vital role in pollination and ecosystem stability, emphasizing their importance in agricultural ecosystems. These findings underscore the necessity of integrated pest management strategies for sustainable *S. bicolor* cultivation in Northern Sumatra, Indonesia. Moreover, they emphasize the significance of biodiversity conservation and effective management practices to maintain ecosystem health and agricultural productivity in the region.

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Conflict of Interest Statement

We have no conflict of interest to disclose.

AI Disclosure

We declare that this manuscript was prepared without the assistance of artificial intelligence. Hence, the content of this paper is original.

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