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Research Article

Abundance And Diversity of Greenhouse Insects in A Tropical Highland Area in Central Nigeria

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ABSTRACT

Greenhouses offer a controlled environment for cultivating crops, especially in highland areas where harsh weather conditions may limit open-field farming. However, they also provide suitable conditions for various insect pests, as such this study aimed at investigating the abundance and diversity of insects in selected greenhouses in a tropical highland area of the Jos Plateau, Central Nigeria, so as to identify the key species and their population. Sampling and collection of insects was carried out monthly from December 2016 to May 2017 using insecticides for greenhouses to knockdown the insects before hand picking them. Insect species recovered were identified using identification keys before the relative abundance and diversity index were computed. A total of fifteen (15) insect species, two hundred and forty-nine (249) individuals belonging to eight (8) Orders were identified. Order Hemiptera having 157 individuals (63.1%) was the most abundant insect Order identified whereas the least being Hymenoptera with 2 individuals (0.80%). Green aphids (*Myzus persicae*) 93(37.35%) were the most abundant while Black digger wasp (*Sphex pensylvanicus*) had the lowest abundance 2(0.81%) and differences between species abundance varied significantly ($p < 0.001$). Insects' occurrence and abundance was highest in December, 2016 (74, 29.72%) compared to March, 2016 which recorded the least number of insects (7, 2.81%) and differences in insects abundance between the months significantly varied ($p < 0.001$). However, the study revealed a moderately low insect diversity level ($H' = 2.0960$) in the greenhouses. This study therefore suggests the need to understand the complex interactions between greenhouse insects and their environment as a driver of insects' abundance.

Keywords: Greenhouses; Insects; Pests; Tropics; Highland area; Species diversity; Jos Plateau

Introduction

Insects are important because of their diversity, ecological role and influence on agriculture, human health and natural resources[1,2]. Insects are the most populated organisms in the world[3]. The total number of insect species on earth is estimated to be 1-3 million, probably representing more than 80-90% of all animal species[1,4-7]. This can be because different species of the insect reproduce very fast and have large number of offsprings. They are highly sensitive to changes in climate of their environment, such as rainfall, temperature, wind, humidity and altitude[1,8]. Insect species diversity is an important factor in the balance of environmental condition. Insects are closely associated with human lives and have great impact on the welfare of humanity in diverse ways[2,9]. A large proportion of the earth's plant species including many trees depends on insects to pollinate their flowers. Therefore, disappearance of insects could lead to extinction of earth's animals because of the disappearance of so much plant life[10,11]. Furthermore, estimating insect diversity has become a topic of global interest as it plays a crucial role in developing effective conservation strategies[12].

Greenhouse agriculture has emerged as a crucial innovation in modern farming, offering a controlled environment for crop cultivation and extending growing seasons. This is particularly important in highland regions, where temperature fluctuations, high humidity and erratic rainfall can limit open-field agricultural productivity[13]. In the highland areas of Nigeria such as Jos Plateau and Mambila Plateau, greenhouses are increasingly used to cultivate high-value crops such as tomatoes, cucumbers, peppers and leafy vegetables throughout the year, thereby improving food security and economic stability[14]. These environments create stable conditions that promote pest development, even when external climatic conditions are less favorable. In these regions, greenhouses serve an even more critical function, allowing for consistent agricultural production in areas that would otherwise be restricted due to cooler climates. While highland temperatures may naturally deter some insect populations, greenhouses counteract these environmental conditions and can, paradoxically, attract and sustain diverse insect communities[15]. However, the favorable microclimatic conditions within greenhouses such as moderate temperatures, high humidity and limited air circulation also create an ideal habitat for a variety of insect pests. These pests can thrive in the warm and humid conditions typical of greenhouses, where the absence of natural predators and limited airflow create an ideal environment for their survival and reproduction[16]. These insects can negatively impact plant health by feeding on foliage, stems and roots; transmitting plant pathogens; and reducing both yield and crop quality. Insects such as whiteflies (*Trialeurodes vaporariorum*), aphids (*Myzus persicae*), thrips (*Frankliniella occidentalis*) and fungus gnats (*Bradysia* spp.) are commonly reported in greenhouse environments and are known to cause significant damage to crops by feeding on plant tissues, transmitting viral pathogens and promoting the growth of secondary infections such as sooty mold[15,16].

Akinlosotu and Okelana[17] investigated the insect pests affecting greenhouse-grown vegetables (mainly tomato, pepper and cucumber) in southwestern Nigeria. The researchers recorded high populations of whiteflies, aphids, thrips and leafminers. These pests were identified as major contributors to yield loss, particularly in greenhouses that lacked effective ventilation or sanitation protocols. Also, in Jos Plateau, Nigeria, Gana and Adebayo[18] conducted a field monitoring of pest populations using yellow sticky traps, visual scouting and insect sweep nets in Greenhouse vegetables. Over 25 insect species were identified, with whiteflies and thrips accounting for over 70% of the captured insects. Population peaks were noted during late vegetative to early flowering stages of the crops. The diversity and abundance of insects in highland greenhouses may differ from those in lowland environments due to the unique interactions between altitude, temperature, humidity and crop type. Despite the increasing adoption of greenhouse farming in highland areas, limited research has been conducted on the insect fauna associated with these protected environments. Understanding the composition and abundance of insect species in these systems is critical for designing effective integrated pest management (IPM) strategies that are location-specific and environmentally sustainable[19]. Furthermore, identifying beneficial insect species such as parasitoids and predators that naturally regulate pest populations is equally important. These organisms play a crucial role in maintaining ecological balance within the greenhouse ecosystem. The use of biological control agents is gaining popularity due to the increasing resistance of pests to chemical insecticides and the growing concern about pesticide residues on food crops. This study, therefore, sought to fill the existing gap in the tropics by assessing the abundance and diversity of insect species in greenhouses situated in Jos, Plateau state. The results will provide additional valuable baseline data that can inform pest control strategies, improve crop yield and support sustainable greenhouse agriculture in similar agro-ecological zones.

Materials and Methods

Study area

This study was conducted in 16 greenhouses around Jos-south Local Government Area of Plateau State from December, 2016 to May, 2017 **(Figure 1)**. Plateau State is located in Nigeria's middle belt, with an area of 26,899 square kilometers. The State has an estimated population of about three million people. It is located between latitude 08°24'N and longitude 008°32' and 010°38'E. Jos is the capital city of Plateau State, North-central Nigeria. Jos is located between Latitude 80° 24'N and Longitude 80° 32' and 100° 38'E. According to the last official national census figures in 2006, Jos North has an area of approximately 291 km^2 and a population of 429,300, while Jos south has an area of about 510 km^2 and a population of 306,716[20]. Jos has a tropical climate and receives about 1,400 mm of rainfall annually, which comes from both conventional and orographic sources, owing to the city's location on the Jos Plateau. Rainfall is abundant from May to September each year, with peaks in July and August[20]. Compared to other parts of Plateau State and Nigeria, the city has a temperate climate, with average monthly temperatures ranging from 21°C and 25°C. Jos and environs also contain a large area of agricultural land. These factors enable farmers to grow a wide variety of tropical and temperate fruits, vegetables and crops that supply communities in neighboring states in North-Central Nigeria[21].

Sampling procedures

Sampling and collection of insects were carried out monthly using insecticides for greenhouses to knock down the insects before hand picking them from dawn to dusk during the study period (December, 2016 to May, 2017). For each sampling day in each month, 50 ml emamectin benzoate and acetamiprid was diluted in 20L of water and pored carefully into a manual knapsack sprayer. With proper personal protective gear, the solution was applied in the greenhouse facilities. Insects that were knock-down were handpicked as described by Tuf[22], this was repeated for each month of collection as a preventive and control protocol for arthropod pest.

Preservation and identification of insects collected

All insects collected were placed in well labeled jars and then wet preserved in 70% ethanol. However, butterflies and moths were dry-preserved in air-tight containers containing silica gel. Representative samples were adequately prepared and mounted in insect boxes using appropriate entomological pins or glued on paper cards before mounting in the insect boxes and identified in the laboratory using identification keys and illustration guides provided by Castner[23], Shattuck[24] and Larsen[25]. Identified insect were then grouped into orders, Families, Genus, Species and common names.

Data analysis

The insect species collected from each sampling sites were pooled and their relative abundance and frequency of occurrence computed by using Minitab Statistical Software version 21.2. Chi-square test was used to compare proportions of the various variables considered. Level of significance was set at P < 0.05. Relative abundance of the insects was determined using the formula[26] below:

Relative abundance of a species =

$$\frac{\text{Number of individuals of the same species} \times 100\%}{\text{Number of individuals of all the species}}$$

While insect species diversity was determined using Shannon-Wiener Index (H´) where H´ is the species diversity index (Shannon-Wiener diversity index); S is the number of species and Ln pi is the inverse proportion of individuals of each species belonging to the ith species of the total number of individuals.

Results

A total of fifteen (15) insect species and two hundred and forty-nine (249) individuals belonging to eight (8) Orders viz., Araneae, Diptera, Lepidoptera, Ordonata, Hemiptera, Homoptera, Coleoptera, Neuroptera and Hymenoptera were caught and identified **(Table 1)**, from the greenhouses. The most abundant insect species identified were members of the Order Hemiptera having 157 individuals (63.1%) followed by the Diptera with 32 individuals (12.85%), Lepidoptera with 26 individuals (10.44%), Araneae with 14 individuals (5.62%), Coleoptera with 8 individuals (3.21%), Neuroptera with 7 individuals (2.81%) and Ordonata with 7 individuals (1.20%) while the least abundant insect species was recorded in Hymenoptera with 2 individuals (0.80%).

The overall result of the relative abundance **(Table 1)** showed that Green Aphids (*Myzus persicae*) with 93(37.35%) recorded the highest abundance, followed by White fly (*Trialeurodes vaporariorum*) 48(19.28%), House fly (*Musca domestica*) 17(6.83%), Swallowtail Butterfly (*Papilio antimachus*) 14(5.62%), Honey bees (*Apis mellifera*) 13(5.22%), Potato tuber moth *(Phthorimaea opercullella*) 12(4.82%), Jumping spider (*Habronattus coecatus*) 9(3.61%), Blow fly (*Lucilia* sp.) 8(3.21%), Lady bug (*Cocrinella septempunctata*) 8(3.21%), Lace wing (*Chrysoperla carnea*) 7(2.81%), Pea leaf miner (*Liriomyza huidobrensis*) 7(2.81%), Green spider (*Peucetia viridans*) 5(2.01%), Damsel fly (*Ischnura* sp.) 3(1.20%) and Pirate bug (*Orius insidiosus*) 3(1.20%) while Black digger wasp (*Sphex pensylvanicus*) had the lowest relative abundance 2(0.81%). Statistical analysis revealed that the relative abundance of the insect species collected in the greenhouses differed significantly (χ^2 = 480.2175, df = 14, P < 0.001).

Insects' occurrence and abundance was highest in December 2016 with a total collection of 74 (29.72%) followed by April and May 2016 having 64.00 (25.70%) insects each then January 2016 with 27 (10.84%) while March 2016 recorded the least number of occurrence and abundance with 7 (2.81%) insects collected as shown in Table 2. Although, there was a significant difference (χ^2 = 103.169, df = 5, P < 0.001) in the abundance of insects sampled across the months, the diversity index as shown in Table 3 indicate that the greenhouses recorded a moderately low species diversity (Shannon-Wiener index = 2.0960).

Table 1: Abundance of Insects in Greenhouse in Plateau state, Nigeria.

Order	**Family**	**Species**	**Common name**	**Abundance (%)**
	Salticidae	*Habronattus coecatus*	Jumping spider	9(3.61%)
Araneae	Oxyopidae	*Peucetia viridans*	Green spider	5(2.01%)
	Calliphoridae	*Lucilia* sp.	Blow fly	8(3.21%)
	Agromyzidae	*Liriomyza huidobrensis*	Pea leaf miner	7(2.81%)
Diptera	Muscidae	*Musca domestica*	House fly	17(6.83%)
	Gelechiidae	*Phthorimaea opercullella*	Potato tuber moth	12(4.82%)
Lepidoptera	Papilionidae	*Papilio antimachus*	Swallowtail Butterfly	14(5.62%)
Ordonata	Coenagrionidae	*Ischnura* sp.	Damsel fly	3(1.20%)
	Aleyrodidae	*Trialeurodes vaporariorum*	White fly	48(19.28%)
	Apidae	*Apis mellifera*	Honey bees	13(5.22%)
	Anthocoridae	*Orius insidiosus*	Pirate bug	3(1.20%)
Hemiptera	Aphididea	*Myzus persicae*	Green Aphids	93(37.35%)
Coleoptera	Coccinellidea	*Cocrinella septempunctata*	Lady bug	8(3.21%)
Neuroptera	Chrysophidae	*Chrysoperla carnea*	Lace wing	7(2.81%)
Hymenoptera	Salticidae	*Sphex pensylvanicus*	Black digger wasp	2(0.81%)
Total				**249**

χ^2 = 480.2175, df = 14, P < 0.001

Table 2: Species Abundance of Greenhouse Insects in Plateau State in Relation to The Period of Collection.

Month/Year	Number of occurrence	Percentage
December 2015	74	29.72%
January 2016	27	10.84%
February 2016	13	5.22%
March 2016	7	2.81%
April 2016	64	25.70%
May 2016	64	25.70%
Total	249	100.00%

$\chi^2 = 103.169$, df = 5, $P < 0.001$

Table 3: Species Diversity of Greenhouse Insects in Plateau State.

Family	Species	No. of Insect	Pi	Ln (Pi)	Pi*Ln (Pi)
Salticidae	*Habronattus coecatus*	9	0.0361	-3.3202	-0.1200
Oxyopidae	*Peucetia viridans*	5	0.0201	-3.9080	-0.0785
Calliphoridae	*Lucilia* sp.	8	0.1928	-1.6463	-0.3173
Agromyzidae	*Liriomyza huidobrensis*	7	0.0321	-3.4380	-0.1105
Muscidae	*Musca domestica*	17	0.0482	-3.0325	-0.1461
Gelechiidae	*Phthorimaea opercullella*	12	0.0281	-3.5715	-0.1004
Papilionidae	*Papilio antimachus*	14	0.0562	-2.8784	-0.1618
Coenagrionidae	*Ischnura* sp.	3	0.0120	-4.4188	-0.0532
Aleyrodidae	*Trialeurodes vaporariorum*	48	0.0522	-2.9525	-0.1541
Apidae	*Apis mellifera*	13	0.0683	-2.6842	-0.1833
Anthocoridae	*Orius insidiosus*	3	0.3735	-0.9849	-0.3678
Aphidoidea	*Myzus persicae*	93	0.0321	-3.4380	-0.1105
Coccinellidea	*Cocrinella septempunctata*	8	0.0120	-4.4188	-0.0532
Chrysophidae	*Chrysoperla carnea*	7	0.0281	-3.5715	-0.1004
Salticidae	*Sphex pensylvanicus*	2	0.0080	-4.8243	-0.0387
Total		**249**			**-2.0960**

$\therefore H' = -(-2.0960) = +2.0960$

Discussion

A total of fifteen (15) species and two hundred and forty-nine (249) individuals belonging to eight (8) insect Orders viz., Araneae, Diptera, Lepidoptera ordonata, Hemiptera, Homoptera, Coleoptera, Neuroptera and Hymenoptera were caught and identified from the greenhouses in this study. Order Hemiptera recorded the highest insect abundance representing 63.1% of the collection. This finding is similar to the study of Yager et al.[7] who also reported Hemiptera as the most dominant Order in their study of insect abundance in the Federal University of Makurdi, Benue state. However, the result of this finding is in contrast with the result of Nandini and Murali[27] who reported Hymenoptera as the most dominant insect Order in their study of insect species in Gulbarga District, Kamataka, India. Furthermore, this result negates the findings of Adeduntan and Olusola[28] who presented Orthoptera as the most dominating insect Order in different forest vegetation types in Ondo State, Nigeria. However, it is worth noting that the variations in these studies can be attributed to the differences in study sites, locations and in environmental characteristics/attributes; also, it could be due to the availability of susceptible hosts in the study environments. In a study conducted by Chebet et al.[29] in the Kenyan highlands, significant differences were also found in insect species composition compared to lowland greenhouses. The findings underscore the importance of site-specific ecological assessments in greenhouse pest management.

The most abundant insect species identified in this study were members of the Order Hemiptera having 157 individuals (63.1%), this result agrees with the work of Yager et al.[7] who also reported Hemiptera as the most dominant species in their study however it differs from the findings of Emmanuel and Olajumoke[9] from Wukari, Nigeria who reported the Order Coleoptera with a relative abundance of 46.41% and Ajayi, et al.[30] from shabu Nasarawa state who reported the Order orthoptera as the most abundant Order with 57.19%. McPherson[31] in a study noted that Hemiptera are integral to many food webs, influencing plant health and population dynamics. Their feeding habits significantly impact agricultural systems, making them both beneficial and detrimental to human interests. Furthermore, research by Hwang et al.[32] indicates that Hemiptera species exhibit a wide range of feeding strategies, which allows them to exploit diverse ecological niches. This adaptability is further enhanced by their ability to reproduce rapidly, leading to population explosions in favourable conditions such as the greenhouses which are known to counteract environmental conditions and can, paradoxically, attract and sustain diverse insect communities[15]. The second most abundant Order in the study is the Order Diptera with 32 individuals (12.85%), followed by Lepidoptera with 26 individuals (10.44%), Araneae with 14 individuals (5.62%), Coleoptera with 8 individuals (3.21%), Neuroptera with 7 individuals (2.81%) and Ordonata with 7 individuals (1.20%) while the least abundant insect Order was recorded in Hymenoptera with 2 individuals (0.80%).

These differences in insect composition may be attributed to differences in sampling techniques, food plant for the insects, predators/parasitoids presence and, other biotic and abiotic factors as reported by Rahmathulla et al.[33].

Green Aphids (*Myzus persicae*) with 93(37.35%) was recorded as the most abundant insect species in this study. This result is in agreement with the report of Doehler et al.[34] who reported that aphids were detected in all monitored greenhouses in their study in the first sampling session while 93% of the sampled greenhouses were infested with aphids during the second sampling session of their study on the effect of landscape on insect pests and associated natural enemies in greenhouse crops. Aphids have been known to be notorious for their rapid reproduction and their role in transmitting diseases like mosaic virus, which affects crops such as tomatoes and cucumbers in greenhouses[16], again their rapid life cycles also enable them to colonize new habitats quickly, out competing other insect groups especially in control environment like the greenhouses[35].

The second most dominant insect species was the White flies (*Trialeurodes vaporariorum*) having 48(19.28%) members. This insect has also been reported in other studies as the most abundant in greenhouses[17,36]. Furthermore, Gana and Adebayo[18] in their study on the monitoring and control of insect pests in greenhouse vegetables in Jos Plateau, Nigeria, recorded over 25 insect species affecting greenhouse vegetables, with white flies and thrips accounting for over 70% of the captured insects. White flies are known to be one of the most damaging pests in Nigerian greenhouses. They feed on plant sap, weakening crops and can also transmit various plant viruses.

Other insect species recorded in this present study include House fly (*Musca domestica*) 17(6.83%), Swallowtail Butterfly (*Papilio antimachus*) 14(5.62%), Honey bees (*Apis mellifera*) 13(5.22%), Potato tuber moth (*Phthorimaea opercullella*) 12(4.82%), Jumping spider (*Habronattus coecatus*) 9(3.61%), Blow fly (*Lucilia* sp.) 8(3.21%), Lady bug (*Cocrinella septempunctata*) 8(3.21%), Lace wing (*Chrysoperla carnea*) 7(2.81%), Pea leaf miner (*Liriomyza huidobrensis*) 7(2.81%), Green spider (*Peucetia viridans*) 5(2.01%), Damsel fly (*Ischnura* sp.) 3(1.20%), Pirate bug (*Orius insidiosus*) 3(1.20%) and Black digger wasp (*Sphex pensylvanicus*) 2(0.81%). The overall findings on the insect species in this study is in line with the findings of Akinlosotu and Okelana (2020) who also investigated the insect pests affecting greenhouse-grown vegetables (mainly tomato, pepper and cucumber) in southwestern Nigeria. The authors recorded high populations of white flies (*Bemisia tabaci*), aphids (*Aphis gossypii*), thrips (*Thrips tabaci*) and leaf miners (*Liriomyza* spp.). These pests were identified as major contributors to yield loss, particularly in greenhouses that lacked effective ventilation or sanitation protocols. The authors also noted that the enclosed greenhouse environment amplified pest population buildup due to limited natural enemies and favorable microclimate conditions. Musa and Okoye[13] in their study in Jos Plateau and Mambilla highlands also revealed that over 65% of farmers experienced persistent infestations of aphids and white flies' infestation despite frequent pesticide use. They attributed the findings to the introduction of many pests through contaminated seedlings and highlighted the fact that highland greenhouses, due to moderate temperatures and continuous cropping, create year-round pest survival niches. The present study also identified some beneficial insect in the greenhouses such as Lady bug (*Cocrinella septempunctata*) 8(3.21%) and Lace wing (*Chrysoperla carnea*) 7(2.81%). Lady bug beetles are known to be natural predators of aphids, whiteflies and other soft-bodied insects, while Lace wing larvae feed on aphids, thrips and white fly eggs, providing a natural control mechanism for pest populations. These natural enemies can play a vital role in reducing pest populations and maintaining ecological balance in the greenhouses[15]. Gurr et al.[37] noted that predatory insects like ladybugs and lacewings help control aphid populations, thereby reducing the need for chemical pesticides while Hoddle et al.[38] advocate for the integration of such beneficial species into IPM programs to reduce dependency on synthetic pesticides, which often lead to resistance and secondary pest outbreaks.

Insects' occurrence and abundance was highest in December 2016 (74, 29.72%) followed by April and May 2016 (64, 25.70% each, respectively) then January 2016 (27, 10.84%) while March 2016 recorded the least number of occurrence and abundance (7, 2.81%). This shows that insect colonization of greenhouse crops is strongly influenced by the time of year, with certain months showing higher abundance due to favorable temperatures and resource availability. Our finding is contrary to the report by Doehler et al.[34] who found that insect colonization was significantly higher in greenhouse strawberry crops during late spring and early summer compared to other months. Also, different generations (cohorts) of pest insects may have varying growth rates and reproductive success depending on the month and associated temperature extremes. For instance, summer cohorts often show higher population growth rates, while spring and autumn cohorts may be more sensitive to temperature fluctuations[39].

The diversity index in this research indicates that the greenhouses recorded a moderately low insect species diversity ($H' = 2.0960$). This is similar to the findings of Yusuf and Afolabi[40] who also found higher pest density but lower overall species diversity in greenhouses in their study on the comparative study of insect diversity in greenhouse vs. open-field cultivation in the Nigerian highlands, attributing their findings to the enclosed ecosystem which serves in favoring only a few dominant pests' species. However, the diversity index of 2.096 recorded in this study differed from the 2.87 - 3.20 range reported by Yager et al.[7] for insect species diversity and abundance in and around Federal University of Agriculture, Makurdi Forestry Nursery, Benue State, Nigeria. Generally, insects play a dual role in greenhouse ecosystems, serving as both beneficial agents and pests. Understanding their dynamics is essential for developing sustainable agricultural practices that enhance productivity while minimizing environmental impacts.

Conclusion

The current study identified two hundred and forty-nine (249) individuals of insects belonging to eight (8) Orders spread across fifteen (15) species in some selected greenhouses in tropical highland area of the Jos Plateau, Nigeria. Order Hemiptera was the most abundant Order representing 63.1% of entire collections. Green aphids (*Myzus persicae*) representing 37.35% of the collection was the most dominant species of insect recorded in this study followed by White flies (*Trialeurodes vaporariorum*) 19.28%. These two species are known as pest that cause extensive damage to plants and crops especially in a control environment like the greenhouses. Other insect species particularly, predatory insects such as Lady bug (3.21%) and Lace wing (2.81%) were also encountered but in low numbers. Generally, however, the finding revealed a moderately low insect species diversity in the greenhouses. Notwithstanding, this study has shown that greenhouses provide a suitable habitat for the occurrence of diverse insect species including insect pests and their predators. The abundance recorded also entail that the environment favours the dynamics and interaction of these different insect species in this habitat. Further study is encouraged to explore the complex interaction of these different insect species in this environment and how this relationship can be explored as a tool for pest management and control in integrated pest management (IPM) system. Lastly, a longitudinal study should be conducted in order to understand how the microclimatic conditions of the greenhouses affect the abundance of these insect species all year round and if the abundance of these insects is associated to particular type of crops cultivated in the greenhouse.

Conflicts of Interest

The authors declare no conflict of interest.

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