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Source: Florida Entomologist, 95(2) : 319-325

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.095.0212

DIEL ACTIVITY OF FAUNA IN DIFFERENT HABITATS SAMPLED AT THE AUTUMNAL EQUINOX

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Abstract

Experiments were conducted to examine the diurnal responses and abundance of arthropods at the autumn equinox in 2010. Experiments were conducted in 3 different fields, each with a different plant species: sunn hemp (*Crotalaria juncea* L.), bahiagrass (*Paspalum notatum* Flugge), and sandbur grass (*Cenchrus* spp.) using a randomized complete block design. Data were collected on numbers of arthropods caught in pitfall traps and on sticky cards. The long-legged flies (Diptera: Dolichopodidae) and thrips (Thysanoptera) collected were consistently diurnal, while ants (Hymenoptera: Formicidae), springtails (Collembola: Entomobryidae), micro-Diptera and tumbling flower beetles (Coleoptera: Mordellidae) were diurnal in one experiment. Elateridae and Aphididae tended to be nocturnal taxa, but plant height had some effect as well because aphid numbers were significantly higher in tall (182.3 cm) sunn hemp than in short (88.1 cm) sunn hemp at night time only. Cicadellidae were active during both day and night time and showed different levels of activity in pitfall traps and on sticky cards. Pitfall traps were found to be very effective for sampling insect taxa including Formicidae, Elateridae, and Collembola, while micro-Diptera, thrips, aphids, and Mordellidae were commonly caught on sticky cards. Cicadellidae and Dolichopodidae were commonly recovered in pitfall traps and on sticky cards.

Key Words: arthropod community, bahiagrass, equinox, nocturnal, pitfall traps, sampling, sandbur, sticky cards, sunn hemp.

Resumen

Se realizaron experimentos para examinar las respuestas diurnas y de abundancia de artrópodos en el equinoccio de otoño en el 2010. Se realizaron los experimentos en tres campos diferentes, cada uno con diferentes especies de plantas: cáñamo de la India (*Crotalaria juncea* L.), pasto de bahia (*Paspalum notatum* Flugge), y el pasto sandbur (*Cenchrus* spp.) utilizando un diseño de bloques completos al azar. Se recolectaron los datos del número de artrópodos capturados en las trampas de caída y en las tarjetas pegajosas. Las moscas de patas largas (Diptera: Dolichopodidae) y trips (Thysanoptera) recogidos fueron consistentemente diurnos, mientras que las hormigas (Hymenoptera: Formicidae), colémbolos (Collembola: Entomobryidae), micro-Diptera y los escarabajos volteretos de las flores (Coleoptera: Mordellidae) fueron diurnos en uno de los experimentos. Los Elateridae y Aphididae tendían a ser los taxones nocturnos, pero la altura de la planta tuvo cierto efecto, así dado que el número de áfidos fueron significativamente mayores en plantas altas de cáñamo de la India (182.3 cm) que en plantas bajas (88.1 cm) de cáñamo de la India solamente durante la noche. Los Cicadellidae fueron activos durante el día y la noche y mostraron diferentes niveles de actividad en las trampas de caída y trampas pegajosas. Las trampas de caída fueron muy eficaces para el muestreo de taxones de insectos diferentes que incluyen Formicidae, Elateridae y Collembola, mientras que los micro-Diptera, trips, pulgones, y Mordellidae fueron comunes en las trampas pegajosas. Los Cicadellidae y Dolichopodidae fueron recuperados comúnmente tanto en las trampas de caída como en las trampas pegajosas.

Diel (24-hour cycle) activity in insects is a well-known phenomenon, with feeding, mating, oviposition, and migration separated among hr of d and night (Fullard et al. 2000; Feer & Pincebourde 2005). Different times for feeding, mating, and migration can lead to use of the same suite of food sources by diverse insect communities (Devries et al. 2008).

Numerous studies have documented diel activity among arthropods. Activity patterns during different times of the d have been shown for butterflies, where some are active throughout the d, while others exhibit their greatest activity at mid-day or are most active during the early morning and/or late afternoon (Novotny et al. 1991; Fullard et al. 2000; Shapiro et al. 2003). Diel activities can vary by the crop type and insect groups. Vickerman & Sunderland (1975) reported greater numbers of arthropods at night in spring barley (*Hordeum vulgare* L.; Poales: Poaceae) and during d in winter wheat (*Triticum aestivum* L.; Poales: Poaceae). Most carabid beetles have been reported as nocturnal, while thrips (Thysanoptera), crab spiders (Araneae: Thomisidae), and jumping spiders (Araneae: Salticidae) are diurnal in nature (Breymeyer 1966; Vickermand & Sunderland 1975). Arthropod families among several orders are diurnal in nature, such as Cicadellidae, Acrididae, Scarabaeidae, Erythraeidae, Lycosidae, and Thomisidae. On the other hand, groups such as Carabidae, Micryphantidae and Diplopoda are generally nocturnal (Schmoller 1971).

Understanding diel activity of insects is helpful for better managing harmful insects using biocontrol and other approaches, or for managing useful insects by manipulating their behavior. For example, Morse & Fritz (1983) found that milkweed (*Asclepias* spp.; Gentianales; Apocynaceae) flowers matured about 8 times more pods when exposed to diurnal pollinators than nocturnal visitors. Information will also be gained for determining the best sampling time for insects. Brown & Schmitt (2001) reported that role of biocontrol agents may be underestimated by sampling them only during daylight hr when they are active at night. Information is available on diel activity of insects in different seasons of the yr, but it is likely to be affected by the relative hr of the d and night at any particular time. It may be especially informative to examine how insect diel activities are allocated when d and night were equal in length (equinox). The present study was conducted to compare the abundance of arthropods between d and night on equinox d. Fields of sunn hemp (*Crotalaria juncea* L.; Fabales: Fabaceae), bahiagrass (*Paspalum notatum* Flugge; Poales: Poaceae), and sandbur grass (*Cenchrus* spp.; Poales: Poaceae) were used in the experiments.

Materials and Methods

Field experiments were conducted at the Experimental Design Field Teaching Laboratory at the University of Florida, Gainesville, Florida (29.650° N, 82.367° W). Autumn equinox d (21-23-IX-2010) were chosen to conduct experiments. Abundance of arthropods was compared between d and night in 3 fields containing different plants: short and tall sunn hemp, bahiagrass, and sandbur gras. The soil was Millhopper sand (loamy, siliceous, hyperthermic, Grossarenic Paleudult, with 92% sand, 3% silt, and 5% clay, and low [< 2%] organic matter). The history of the experimental sites involved growing sunn hemp and cowpea (*Vigna unguiculata* (L.) Walp.) as cover crops during the previous yr. Day and night temperatures were 28.6 °C and 19.6 °C on Sept 22, and 28.1 °C and 19.8 °C on Sept 23, respectively (FAWN 2011).

Sunn Hemp Experiment

This experiment was conducted in a field of sunn hemp that was approximately ½ ha in size. Sunn hemp (var. 'Tropic Sun') was planted during the last week of Jun, 2010, and the crop was grown using standard practices (Treadwell & Alligood 2008). On Sep 21, the 3 mo-old sunn hemp plants varied in size throughout the field. The experiment was set up in a randomized complete block design with time of the d (day/night) as the main treatment and plant height (short/tall) as the sub treatment. Five locations (replications) with each plant height were selected for sampling within this field. At each location, a patch (approx. 1 m^2) of tall and a patch of short sunn hemp plants were identified as subplots for sampling. Distances between the tall and short subplots of sunn hemp within each pair ranged from 3-5 m; distance between replicate locations was > 7 m. The experiment was started at dawn on the morning of 21 Sep and terminated at dawn the next d. Weeds were found at some places in the field, but only a few weeds were present near locations where traps were set for sampling. Weeds identified from this site included evening primrose (*Oenothera laciniata* Hill; Myrtales: Onagraceae), Florida pusley (*Richardia scabra* L.; Rubiales: Rubiaceae), purple nutsedge (*Cyperus rotundus* L.; Poales: Cyperaceae), clover (*Trifolium* spp.; Fabales: Fabaceae), crabgrass (*Digitaria sanguinalis* (L.) Scop.; Poales: Poaceae), cudweed (*Gnaphalium purpureum* L.; Asterales; Asteraceae), goosegrass (*Eleusine indica* Gaertn.; Poales: Poaceae), and purslane (*Portulaca oleracea* L.; Caryophyllales: Portulaceae).

Data Collection

Pitfall and sticky cards were used to measure the abundance of arthropods in selected plots. Unbaited plastic sandwich containers (14 cm × 14 cm × 4 cm, containing 532 ml of water) were used as pitfall traps. A single pitfall trap was placed in each subplot, and buried in soil so that the upper edge was flush with the soil surface. The traps were filled ¾ with water, along with 3 to 4 drops of dish detergent (Ultra Joyâ, Procter and Gamble, Cincinnati, Ohio) to break surface tension, ensuring that the insects would remain in the trap. Yellow, unbaited, Pherocon® AM sticky cards (Great Lakes IPM, Vestaburg, Michigan) were placed with the lower edge 5 cm above the soil surface in each subplot. Two sides of the sticky card were exposed, each 14 cm wide × 23 cm high, thus the effective height sampled was 5-28 cm above the soil surface. One trap of each type (pitfall and sticky card) was placed in each of the paired short and tall sunn hemp subplots on the morning of 21 Sep just before sunrise (6:30-7:00 am, Eastern Daylight Saving Time)). Traps set up in the morning were replaced with new ones on the same evening just after sunset (7:00-7:30 pm), which were collected at dawn the next d. The collected pitfall traps were covered with lids, sticky cards were wrapped in plastic food wrap (Stretch-tite®, Polyvinyl Films Inc., Sutton, Massachusetts), and were brought to laboratory and stored in refrigerator at 4 °C until processed. Arthropods collected in both kinds of traps were identified to order, family, and when possible to genus or species level using a dissecting microscope. Representative samples of arthropods in pitfall traps were transferred and stored in 70% ethanol in vials.

Bahiagrass and Sandbur Grass Experiments

These experiments began at sunrise on 22 Sep and terminated at sunrise on 23 Sep, and were conducted in fields of bahiagrass and sandbur grass (approx. ¼ ha each) Procedures remained the same as for the sunn hemp experiment with a few changes. Each experiment was conducted in a randomized complete block design with time of the d (day/night) as the only treatment. No sub-treatment of plant height was used in these experiments because plant height was relatively uniform in each field. The sandbur was ≈30 cm tall and bahiagrass was mowed periodically and maintained at a height of 5-10 cm. Procedures for insect trapping and data collection remained the same as in the sunn hemp experiment.

Data Analysis

All statistical analyses were performed using the Statistical Analysis System (SAS) package (version 9.1; SAS Institute, Cary, North Carolina). Data for the sunn hemp experiment were analyzed using factorial analysis of variance (PROC ANOVA procedure of SAS) to examine the effects of time of d, plant height, and their interactions on arthropod abundance. Data for other 2 experiments were analyzed using one-way ANOVA to examine the effect of time of d on arthropod abundance.

Results

Sunn Hemp Experiment

Time of d affected the arthropod catch differently in different kinds of traps. In pitfall traps, the numbers of ants (*Solenopsis invicta* Buren and *Dorymyrmex bureni* Mayr, Formicidae), leafhoppers (*Empoasca fabae* [Harris], Cicadellidae), long-legged flies (*Asyndetus* spp., Dolichopodidae), and micro-Hymenoptera (small parasitoid wasps) collected were significantly more abundant during the d than at night (Table 1). However, click beetles (*Conoderus bellus* Say, Elateridae) were present only at night. Spiders (Araneae) and Collembola (mainly Entomobryidae with some Sminthuridae) were not affected by time of d. On sticky cards, the numbers of long-legged flies, tumbling flower beetles (*Mordellistena cervicalis* LeConte, Mordellidae), thrips (Thripidae), and micro-Diptera (mainly fungus gnats, Sciaridae) were greater during d (Table 1). Leafhoppers and aphids (Aphididae) were more common at night, and Bibionidae (*Plecia nearctica* Hardy) did not differ in numbers between d and night sampling.

Plant height of sunn hemp (short [mean = 88.1 cm] and tall [mean = 182.3 cm]) affected different arthropods in different ways. More Dolichopodidae were found in pitfall traps under tall sunn hemp than short sunn hemp (Table 1). No effect of plant height was found for most arthropod groups.

However, a significant ($P < 0.05$) interaction between time of d and plant height was observed for aphids and thrips collected on sticky cards (Table 1). Aphid numbers were greater in tall sunn hemp during night time, while thrips numbers were greater in short sunn hemp during d time (Table 1).

Bahiagrass Experiment

In pitfall traps in bahiagrass, only numbers of *Asyndetus* spp. (Dolichopodidae) were significantly ($P < 0.05$) higher during day than night (Table 2). Insects collected using sticky cards were not affected ($P > 0.05$) by treatments.

Sandbur Experiment

In sandbur grass, numbers of Collembola and Dolichopodidae in pitfall traps were higher during d than night (Table 3). On sticky cards, Dolichopodidae, micro-Diptera, and thrips numbers were significantly ($P < 0.05$) higher during the day, but Cicadellidae were more abundant at night.

Discussion

Different taxa exhibited different diel activity in the current study. Numbers of Formicidae, Dolichopodidae, micro-Hymenoptera, thrips, Collembola, micro-Diptera, and Mordellidae were higher during the d in at least 1 experiment, while numbers of Elateridae and aphids were greater at night. Diel activity was mixed for Cicadellidae. The most consistent effects were observed with Dolichopodidae and thrips, both of which were higher during the d in 2 or more experiments.

Diel activities of different arthropods can vary widely, even among related taxa. In Colorado alpine tundra, the adults of wolf spiders (Arachnida: Araneae: Lycosidae), and crab spiders

TABLE 1. EFFECT OF MAIN TREATMENT (TIME OF DAY) AND SUB-TREATMENT (PLANT HEIGHT) ON ARTHROPODS (NUMBERS/PITFALL TRAP OR STICKY CARD) IN SUNN HEMP FIELD, GAINESVILLE, FLORIDA, 2010.

	Time of day				Plant Height				Time × Height	
Insect taxa	Day*	Night*	*F* value	*P* > *F*	Short*	Tall*	*F* value	*P* > *F*	*F* value	*P* > *F*
					Pitfall traps					
Formicidae	52.6 ± 4.3	21.6 ± 4.5	22.56	0.001	38.9 ± 6.9	36.8 ± 6.8	0.11	0.750	0.29	0.599
Collembola	8.4 ± 2.4	3.8 ± 1.3	2.81	0.113	8.0 ± 2.7	4.2 ± 0.9	1.92	0.185	0.05	0.830
Araneae	5.6 ± 2.2	3.7 ± 2.6	0.29	0.602	6.0 ± 3.1	3.3 ± 1.3	0.58	0.459	0.10	0.761
Cicadellidae	18.2 ± 2.5	5.3 ± 1.1	21.98	0.001	10.7 ± 2.3	12.8 ± 3.3	0.58	0.456	1.27	0.277
Dolichopodidae	8.2 ± 2.4	3.1 ± 1.2	4.52	0.049	3.1 ± 0.8	8.2 ± 2.6	4.52	0.049	1.89	0.188
Micro-Hymenoptera	2.0 ± 0.6	0.4 ± 0.2	6.17	0.025	0.8 ± 0.36	1.6 ± 0.79	1.54	0.232	0.00	1.000
Elateridae	0.0 ± 0.0	2.4 ± 0.7	12.80	0.003	0.8	1.6	1.42	0.250	1.42	0.250
					Sticky cards					
Bibionidae	1.9 ± 1.2	0.0 ± 0.0	2.71	0.119	1.7 ± 1.2	0.2 ± 0.2	1.69	0.212	1.69	0.212
Dolichopodidae	11.2 ± 2.3	0.3 ± 0.2	19.83	0.001	5.4 ± 2.1	6.1 ± 2.8	0.08	0.779	0.14	0.718
Thripidae	9.2 ± 2.8	0.0 ± 0.0	18.96	0.001	7.5 ± 2.9	1.7 ± 1.3	7.53	0.014	7.53	0.015
Sciaridae	7.1 ± 2.4	1.7 ± 0.3	4.48	0.050	4.6 ± 2.0	4.2 ± 1.8	0.02	0.877	0.06	0.817
Mordellidae	1.2 ± 0.5	0.0 ± 0.0	6.70	0.020	0.2 ± 0.2	1.0 ± 0.5	2.98	0.104	2.98	0.104
Cicadellidae	0.3 ± 0.2	2.1 ± 0.5	9.26	0.008	1.1 ± 0.5	1.3 ± 0.5	0.11	0.740	0.46	0.509
Aphididae	0.0 ± 0.0	10.5 ± 3.6	220.5	<0.001	0.0 ± 0.0	10.5 ± 3.6	220.5	<0.001	220.5	<0.001

Please see text for more detailed identification of insect taxa.
*Data are means ± standard error of 5 replications.

Table 2. Effect of main treatment (time of day) on arthropods (numbers/pitfall or sticky card) in Bahiagrass Field, Gainesville, Florida, 2010.

Arthropod taxa	Day*	Night*	*F* value	*P* > *F*
		Numbers/pitfall trap		
Formicidae	24.4 ± 9.5	3.2 ± 1.1	4.92	0.057
Collembola	10.0 ± 3.7	11.0 ± 3.2	0.04	0.843
Cicadellidae	2.0 ± 1.1	0.4 ± 0.2	2.21	0.176
Sciaridae	1.2 ± 0.8	2.2 ± 1.2	0.51	0.498
Dolichopodidae	11.8 ± 4.2	0.0 ± 0.0	7.76	0.024
Araneae	0.4 ± 0.2	0.0 ± 0.0	2.67	0.141
		Numbers/sticky card		
Micro-Diptera	6.4 ± 2.7	1.6 ± 0.5	3.02	0.121
Cicadellidae	0.0 ± 0.0	0.8 ± 0.4	4.57	0.065
Thripidae	2.2 ± 1.9	2.8 ± 1.9	0.05	0.830
Dolichopodidae	8.0 ± 3.9	0.0 ± 0.0	4.32	0.071
Bibionidae	1.0 ± 0.6	0.0 ± 0.0	2.50	0.153

Please see text for more detailed identification of insect taxa. *Data are means ± standard error of 5 replications.

(Arachnida: Araneae: Thomisidae) were mainly collected during the d, while ground beetles (Insecta: Coleoptera: Carabidae), and dwarf spiders (Arachnida: Araneae: Micryphantidae) were common at night (Schmoller 1971). Brown & Schmitt (2001) collected predators that included chrysopids (Insecta: Neuroptera), and *Leptothrips mali* (Fitch) (Insecta: Thysanoptera: Phlaeothripidae) mainly at night or dawn using limb jarring in fruit orchards in West Virginia. During a study on arthropods in winter wheat and spring barley, more Thysanoptera were found during the d, and more Coleoptera at night in vacuum and sweep net samples (Vickernam & Sunderland 1973).

In the present study, the potato leafhopper, *E. fabae* (Cicadellidae), was active often, but at different levels at different times. In the sunn hemp experiment, they were more common in pitfall traps during the d and on sticky cards during the night. This suggests that they are active all the time, but more active at night, when they reach higher levels. In day potato leafhoppers may be crawling or moving near the ground but not so high that they reach the sticky cards, yet they may be more active and jumping higher at night so that they are captured on sticky cards. These observations suggest that further study is needed to better define the diel activity cycles of *E. fabae* and other cicadellids. In the Colorado alpine tundra, the adults of leaf-hoppers (Insecta: Hemiptera: Cicadellidae), were mainly collected during day (Schmoller 1971). Diel activity may be related with insect color to some extent. It has been suggested that arthropods active at night may be inconspicuously colored because predators use visual cues to find prey under nocturnal conditions (Chuang et al. 2007). It is unclear if this may be a

Table 3. Effect of main treatment time of day on arthropods (numbers/pitfall or sticky card) in Sandbur Grass Field, Gainesville, Florida, 2010.

Arthropod taxa	Day*	Night*	F value	P > F
		Numbers/pitfall trap		
Formicidae	86.8 ± 43.3	18.2 ± 9.3	2.40	0.156
Collembola	13.8 ± 2.1	5.0 ± 1.5	12.21	0.008
Cicadellidae	5.8 ± 1.8	4.0 ± 1.0	0.76	0.408
Sciaridae	0.2 ± 0.2	0.0 ± 0.0	1.00	0.347
Dolichopodidae	5.0 ± 1.5	0.4 ± 0.4	8.60	0.019
Araneae	1.4 ± 0.4	1.2 ± 0.7	0.06	0.817
		Numbers/sticky card		
Sciaridae	4.8 ± 1.2	0.8 ± 0.4	9.52	0.015
Cicadellidae	0.2 ± 0.2	4.8 ± 1.7	7.35	0.027
Thripidae	71.6 ± 16.9	0.0 ± 0.0	18.01	0.003
Dolichopodidae	3.2 ± 0.4	0.4 ± 0.4	26.13	0.001
Bibionidae	1.8 ± 1.2	0.0 ± 0.0	2.61	0.145

Please see text for more detailed identification of insect taxa. *Data are means ± standard error of 5 replications.

factor with Cicadellidae, such as *E. fabae*, which is light green in color and may blend in with the plant's color.

Several factors may affect the difference in arthropod abundance between d and night. In our study, the temperature difference between d and night was 9.1 °C. In a detailed study conducted on catches of noctuids in Australia, it was concluded that night temperature, wind, and nocturnal illumination were the most important factors influencing the catch (Persson 1976; Thomas 1996). Assuming that only the active portion of the population was caught in traps, then the actual population, which consists of both active and passive components, would be higher than that caught in traps. Further studies, probably in growth chambers, could determine whether temperature or light is the more critical in affecting the abundance of the arthropods captured in the current study.

Activity and occurrence of different arthropods varied among the different plant systems. Adults of Formicidae, Collembola, Cicadellidae, micro-Diptera, Dolichopodidae, Araneae, thrips, and Bibionidae were observed in all 3 systems, i.e. sunn hemp, bahiagrass, and sandbur. On the other hand, micro-Hymenoptera, Elateridae, Mordellidae, and Aphididae were found only in sunn hemp. Several of these insect groups are pollinators (micro-Hymenoptera and Mordellidae) and this could be the reason behind their abundance in sunn hemp. It may also be due to more plant diversity, because some weeds were present in sunn hemp while the other fields were relatively free of weeds. Previous work showed that host plants could be a factor that determines insect species richness (Neuvonen & Niemelä 1981). In a study conducted in Mexico and USA, species richness of gall-inducing insects was positively correlated with number of woody host plant species (Blanche & Ludwig 2001).

We used 2 different methods for collection of arthropods in order to provide a wide range of different taxa. Pitfall traps have been documented as a best sampling method for fauna that run on the soil surface (Williams 1959; Greenslade 1964; Borror et al. 1989; Lindsey & Skinner 2001). Sticky cards were used successfully by HansPetersen et al. (2010) to sample aerial fauna, especially aphids, thrips, and other flying insects. White sticky cards and marking with ultraviolet dust were useful to sample love bugs, *Plecia nearctica*, in Florida (Thornhill 1976), and they were collected on the yellow sticky cards in the current study as well. Dolichopodidae (long-legged flies) are mainly predatory in nature and can be sampled using both pitfall and sticky cards (Gill et al. 2011). Many different sampling methods are available (Borror et al. 1989), so other methods could be tried as well to reveal trends in other insect groups.

Conclusions

The present study suggests that the arthropod activity varied with respect to time of the d and plant height at the autumnal equinox. Dolichopodidae and thrips were consistently more active during the d, while Formicidae, Collembola, and Mordellidae were more active at day in 1 of 3 experiments. Elateridae and Aphididae were more active at night, while some taxa, i.e. Araneae, micro-Diptera, and Bibionidae, were not affected by time of the d. Mixed results with the potato leafhopper, *E. fabae* (Cicadellidae), suggest different activity patterns during d and night that require further research for elucidation. This information may be helpful in learning differential environmental effects on habits of specific insects and therefore could be used in developing pest management options.

Acknowledgments

The authors thank Navneet Kaur for assistance in the field and Rosalie Koenig for providing field space for conducting experiments. The authors thank Gary Steck and Lyle Buss for assisting with insect identifications and Rajinder Mann for reviewing this manuscript. Mention of any trade names or products does not imply endorsement or recommendation by the University of Florida or USDA.

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