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***Anastrepha* species (Diptera: Tephritidae): patterns of spatial distribution, abundance and relationship with weather in three environments of Midwest Brazil**

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**Abstract**

Fruit flies (Diptera: Tephritidae)are a major problem in the production of fruits and vegetables globally. Thus, information about spatial distribution and population dynamics of pest species is important for horticulture. The aims of this research were: to evaluate quantitatively the occurrence of *Anastrepha* Schiner species caught in McPhail traps throughout the year in a native forest, a backyard orchard, and a commercial orchard; to determine the spatial distribution type of *Anastrepha* species in those environments, and to investigate the relationship between *Anastrepha* species abundance and weather. We used McPhail traps with food bait (i.e., hydrolyzed corn protein at 5%). *Anastrepha* species adults were sampled weekly, but the data were pooled by month before analysis: in general (for all environments) and for each environment. We found a positive correlation between abundance of *Anastrepha* species and the seasons. In general, winter was the season with highest abundance and species richness. Among the environments, we found greatest abundance and species richness in the backyard orchard, followed by the native forest and the commercial orchard. In the latter environment, we found a higher abundance of *Anastrepha* species in summer and greater species richness in the spring. *Anastrepha* species adults showed an aggregated spatial distribution. Relative humidity and wind speed influenced the number of *Anastrepha* species caught in the traps.

Key Words: aggregation index; fruit fly; native forest; orchard; species richness

**Resumen**

Las moscas de la fruta (Diptera: Tephritidae)son un problema importante en la producción de frutas y verduras a nivel mundial. Por lo tanto, la información sobre su distribución espacial y dinámica poblacional de las especies son importantes para la horticultura. Los objetivos de esta investigación son: Evaluar cuantitativamente la presencia de especies de *Anastrepha* Schiner capturadas en trampas McPhail durante las estaciones en: bosque nativo, huerto de patio y huerta comercial; conocer el tipo de distribución espacial de la especie *Anastrepha* en esos ambientes y buscar alguna relación entre las poblaciones de las especies de *Anastrepha* y el clima. Utilizamos trampas McPhail con cebo de alimentos (la proteína de maíz hidrolizada al 5%). Los adultos de las especies de *Anastrepha* se muestrearon semanalmente, pero los datos se agruparon por mes, antes del análisis: general y para cada ambiente. Hubo una correlación positiva entre las poblaciones de especies de *Anastrepha* y las estaciones. En general, el invierno es la estación con mayor abundancia y mayor riqueza de especies. Entre los ambientes, hubo mayor abundancia y riqueza de especies en el huerto de patio, seguido por el bosque nativo y el huerto comercial. En este último, hubo mayor abundancia en verano y mayor riqueza de especies en la primavera. Los adultos de las especies de *Anastrepha* muestran distribución espacial agregada. Hay influencias de la humedad relativa y la velocidad del viento en la abundancia de especies de *Anastrepha* capturadas en las trampas.

Palabras Clave: índice de agregación; moscas de la fruta; bosque nativo; huertos; riqueza de especies

The international trade of tropical fruit generates billions of dollars annually, and Latin America and the Caribbean are the largest exporters (FAO 2010). Brazil produces around 43 million tons of fruit and is the third largest producer in the world, after China and India (INCT 2009).

Pests are one of the principal problems faced by fruit farmers throughout the world. Among them are frugivorous dipterans, especially some Tephritidae species. The larvae of these insects feed on fruit pulp and have significant impacts on fruit production (Gonçalves et al. 2006; Garcia & Norrbom 2011). Some Tephritidae larvae can feed on other plant parts, such as flower buds, leaves, and seeds (Uchoa 2012). Hence, due to their high damage potential, studies on their biology, behavior, monitoring, and management strategies have been carried out throughout the world, in Papua New Guinea, Turkey, Tanzania, Mexico, and Spain (Novotny et al. 2005; Genç 2008; Mwatawala et al. 2009; Quintero Fong et al. 2009; Urbaneja et al. 2009, respectively).

In Brazil, species of *Anastrepha* Schiner, *Ceratitis capitata* (Wiedemann), and *Bactrocera carambolae* Drew & Hancock are considered to be the most important fruit crop pests. In the country, 14 *Anastrepha* species and *Ceratitis capitata* are known for their ability to feed on a large number of host plants (Uchoa 2012). Economic losses to fruit production may reach between 120 and 200 million US dollars annually, which includes the costs of insecticide application (Felix et al. 2009) and costs caused by commercial restrictions imposed by countries that import Brazilian fruit (Paranhos et al. 2007).

For optimal insect pest management it is important to know the spatial distribution of the pests, as well as their relationship with weather (Barbosa 1992). There are no studies on the spatial distribution patterns of fruit flies in Mato Grosso do Sul state (Midwest Brazil). Hence, the aims of this study were: (i) to quantitatively assess the occurrence of *Anastrepha* species captured in McPhail traps throughout the year in a native forest and in backyard and commercial orchards with several fruit crops; (ii) to describe the population patterns of *Anastrepha* species spatial distribution in 3 environments (i.e., native forest, backyard orchard, and commercial orchard); and (iii) to test for a possible influence of weather on this guild of *Anastrepha* fruit flies in the 3 environments.

**Material and Methods**

STUDY AREA

We sampled *Anastrepha* species with McPhail traps in a 43.0 ha native forest (22.2000000°S, 54.9166667°W ), a 0.5 ha backyard guava orchard (22.2000000°S, 54.9166667°W), and a 2.5 ha commercial guava orchard (22.2166667°S, 54.7166667°W) in Dourados, Mato Grosso do Sul state, Midwest Brazil, weekly from Jun 2005 to Jun 2007. The altitude in the 3 environments was approximately 430 m.

The regional climate is tropical semi-humid and in some areas high-altitude tropical, with dry winters and rainy summers. Due to the longitudinal position of South America, the atmospheric dynamics of this region is subject to inter-tropical and extra-positive centers of action with highly negative and subtropical pressures, represented by the Amazon and Chaco depressions (Peel et al. 2007).

SAMPLING

We distributed McPhail traps randomly on host plants, at 1.80 m aboveground, in the 3 areas: a native forest (8 traps), a backyard orchard (8 traps), and a commercial orchard (10 traps). The distances between the traps were 30 m in the orchards and 100 m in the native forest.

We used hydrolyzed corn protein (BioAnastrephaTM, BioControle Métodos de Controle de Pragas Ltda., Indaiatuba, Brazil) at 5% as food bait, which was replaced weekly. The flies captured in traps were collected weekly, placed in vials with 85% ethanol, and sent to the Laboratório de Insetos Frugívoros at the Universidade Federal da Grande Dourados. Mean monthly data on abiotic factors (e.g., rainfall, temperature, wind speed, and relative humidity) were provided by the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) Meteorological Station at Centro de Pesquisa Agropecuária Oeste (CPAO), Dourados, Mato Grosso do Sul state, Brazil.

STATISTICAL ANALYSIS

We used the non-parametric Kruskal-Wallis test, with comparison by the Dunn–Bonferroni bilateral test (*P* < 0.01). The calculations take in consideration only the dominant and predominant species, as indicated by an n test.

The software AnaFau by Moraes et al. (2003) was used to calculate the faunistic indices of dominance, abundance, frequency, constancy, and diversity, such as Shannon–Weaver (H') and equitability of Hill.

To investigate the spatial distribution of *Anastrepha* fruit fly species collected in the traps, we first considered all 3 areas separately. We used Morisita’s dispersion indices, average variance, and k-exponent to test whether the fruit flies were distributed randomly or were clustered (Southwood 1978; Elliot 1979).

To estimate theoretical frequency distributions, we used the negative binomial, positive binomial, and Poisson distributions, to determine the model that would fit the observed frequency (Young & Young 1998). The commercial orchard had insecticide applications, therefore, we also analyzed the distribution after excluding the commercial orchard from the data set.

The population levels were accessed by the index fruit flies/trap/day (FFTD), being FFTD = N/T × D. Where N = number of fruit flies caught, T = number of evaluated traps, and D = interval in days between the collections, according to Salas & Chavez (1981). The correlation analysis between the FFTD index and environmental factors was done using Spearman's non-parametric correlation coefficient (α < 0.05) (Dawson & Trapp 2003).

The managers of the commercial orchard applied insecticide for fruit fly control. Therefore, this site was excluded from a second FFTD index analysis to verify if the correlation between FFTD index and the weather remained in the other environments.

The assumptions of the model for the diagnosis of multicollinearity, normality, homogeneity, and an independence of the errors were oriented. Variables that had a variation interaction factor (VIF) above 10 were eliminated from the model, accepting the index of 1,304 and a degree of tolerance above 0.76%, according to Field (2009). Normality and homogeneity were validated graphically. The independence assumption was validated with the Durbin–Watson statistic (d = 1.79), as described in Maroco (2007). With these evaluations and assumptions, the best variables to predict the model were: RH WS. To evaluate the effect of the independent variables (i.e., RH and WS) upon the dependent variables (i.e., FFTD) an analysis of variance (ANOVA) was completed in software BioEstat 5.3 (Ayres et al. 2007).

**Results**

OCCURRENCE AND POPULATION PATTERNS IN 3 ENVIRONMENTS

We captured 3,507 *Anastrepha* species adults in the 3 sampled areas during the weekly evaluations for a 24 mo period. The samples ranged from 0 to 362 individuals, totaling 301 *Anastrepha* species adults in the native forest, 2,940 in the backyard orchard, and 266 in the commercial orchard (Table 1).

The population patterns of *Anastrepha* species differed statistically within each environment, and between the 3 environments. In the native forest, the number of *A*. *sororcula* Zucchi caught in traps during the study differed from all other species (p < 0.01). In this environment, *A. sororcula* and *A*. *montei* Lima were the dominant species. In the backyard orchard, *A*. *fraterculus* (Wiedemann), *A*. *obliqua* (Macquart), and *A*. *sororcula,* were dominant but *A*. *obliqua* differed significantly (p < 0.01) in the total number caught compared with *A*. *sororcula* and *A*. *fraterculus*. In the commercial orchard, *A*. *sororcula* was dominant, differing significantly (p < 0.01) in the number caught during the study from all the other co-occurring species. The analysis of the data pooled for the 3 environments showed that among the dominant species, *A.* *obliqua* and *A*. *sororcula* differed significantly (p < 0.01) in the total number caught compared with *A*. *fraterculus* (Table 1).

FRUIT FLIES IN THE SEASONS

In the native forest, the highest capture of *Anastrepha* species occurred in the winter (Jun 21 to Sep 20), with the summer (Dec 21 to Mar 20) being the season with lowest abundance. In the backyard orchard, the highest capture of fruit flies also occurred in the winter, differing significantly from the second highest capture in the spring (Sep 21 to Dec 20). Both seasons differed significantly (p < 0.001) from summer and autumn (Mar 21 to Jun 20), which had the lowest captures. On the other hand, in the commercial orchard, the highest capture of *Anastrepha* species occurred in the summer, with the winter being the season with the lowest abundance of fruit flies. The backyard orchard differed statistically compared with the other environments in the number of *Anastrepha* species females captured, totaling 1,498 individuals (Table 1).

Considering the seasonal abundance of different species, the abundance of fruit flies in winter differed significantly (p < 0.01) from the abundance in spring and autumn. The species *A.* *obliqua* and *A*. *sororcula* were more abundant in the winter and spring than the other seasons, whereas *A. fraterculus* and *A*. *montei* had higher populations in the winter compared with other seasons (Table 1).

INDICES OF FRUIT FLIES IN THE ENVIRONMENTS

Herein, of the sampled speciesof *Anastrepha* considered as fruit pests, *A*. *fraterculus*, *A*. *sororcula,* and *A*. *pseudoparallela* (Loew) were dominant species in the native forest, with *A*. *montei* and *A*. *sororcula* being considered indicators of that environment. In the backyard orchard, *A*. *fraterculus*, *A*. *obliqua*, *A*. *sororcula,* *A*. *pseudoparallela*, and *A*. *montei* occurred as super dominant. In this environment, *A*. *obliqua*, *A*. *sororcula*, and *A*. *fraterculus* were considered to be indicators. In the commercial orchard, *A. sororcula* was super dominant and an indicator of that environment (Table 2).

In general, the species present represented the environments. In the native forest, *A*. *sororcula* and *A*. *montei* were highly abundant, very frequent, constant, and dominant. In the backyard orchard, *A*. *obliqua*, *A*. *sororcula,* and *A*. *fraterculus* were super abundant, super dominant, super frequent, and constant. In the commercial orchard, *A*. *sororcula* was super abundant, super dominant, super frequent, and constant (Table 2).

PATTERN OF SPATIAL DISTRIBUTION

The dispersion index, variance-to-mean ratio (*I*), presented significant values (above 1.0) in the 3 environments (i.e., native forest, backyard orchard, and commercial orchard). The exponent k of the negative binomial calculated for the number of *Anastrepha* species adults caught in traps, in all the evaluated environments presented positive and significant values, above zero, except in the commercial orchard, with 2 negative values. For the theoretical frequency distributions (i.e., Poisson, negative binomial, and positive binomial) during the seasons, we observed that in the spring and autumn, *Anastrepha* species presented a strongly aggregated distribution pattern (Tables 3 and 4). There was no definite spatial distribution pattern of *Anastrepha* species in the winter (Tables 4 and 5).

The populations of *Anastrepha* species did not present an adjustment to the uniform spatial distribution pattern (i.e., binomial positive) or to the random spatial distribution (i.e., Poisson) in any of the evaluated environments. In fact, *Anastrepha* species adults presented a strongly aggregated spatial distribution in a natural environment (i.e., native forest) and in the backyard orchard, being characterized as moderately aggregated in the commercial orchard (Tables 3–5).

CORRELATION WITH WEATHER

The adjusted model was highly significant for RH and WS, and accounted for 93.1% of the total variability in the number of *Anastrepha* species adults caught in the traps per 30 d interval. The proportion of the variability was high following the prediction model: FFTD = 60.304 + 0.742 RH − 5.754 WS. Among the variables tested in the correlation, RH and WS were highly significant (p > 0.001) by ANOVA, suggesting that it was not necessary to add other variables to verify the variation of the FFTD index (Table 6).

The prediction was 0.742 fruit flies per trap per 30 d interval (FFTD) for every 1% increase in RH during this interval, considering constant WS. There was a reduction of −5.754 FFTD for each meter per second increase in WS, when RH remained constant (Table 6).

**Discussion**

FRUIT FLY SPECIES ABUNDANCE BY ENVIRONMENT

Fourteen species of *Anastrepha* were sampled in the 3 environments, 9 species in the native forest, 11 in the backyard orchard, and 9 in the commercial orchard. The species found exclusively in the native forest environment were: *A. amita* Zucchi, *A*. *barnesi* Aldrich and *A*. *elegans* Blanchard. *Anastrepha* *dissimilis* Stone and *A*. *serpentina* (Wiedemann) were found exclusively in the backyard orchard environment. Most of the species (9) were common for both backyard and commercial orchards (Table 1).

*Anastrepha amita*, *A*. *barnesi*, and *A*. *elegans* feed on native host fruit from Atlantic forests, such as *Citharexylum myrianthum* Cham. (Verbenaceae), *Pouteria torta* Mart. (Radlk; Sapotaceae), and *Chrysophyllum gonocarpum* (Mart. & Eichler) Engl. (Sapotaceae), respectively (Souza-Filho et al. 1999; Garcia et al. 2008). It is probable that these species occur in the native forest, a part of Fazenda Coqueiro, Dourados, a forest fragment with phyto-physiognomy of Atlantic forest.

The species present in the backyard orchard and in the commercial orchard are all associated with fruit crops, mainly Passifloraceae, Myrtaceae, and Euphorbiaceae (Uchoa 2012). The abundance of fruit flies was highest in the backyard orchard. This result can be explained by the higher diversity of host fruit cultivated in this environment, and because the site was connected to a riparian forest, which provided an access corridor to several native forest fragments in the Dourados region.

INDICES OF FRUIT FLIES IN THE ENVIRONMENTS

In the native forest, no super dominant, super abundant, and super frequent species occurred. This is expected, due to the balance of nature, where the fruit trees are spaced by chance. On the other hand, in backyard and commercial orchards, the most dominant, abundant, frequent, and constant species were: *A. fraterculus*, *A*. *obliqua,* and *A*. *sororcula* (Table 2). This result was expected, because these 3 species are polyphagous and key pests on fruit crops (Uchoa 2012).

PATTERN OF SPATIAL DISTRIBUTION

In the native forest (Table 3) and in the backyard orchard (Table 4), the spatial distribution of *Anastrepha* species was aggregated (except in Jan, May, Jul, and Aug). In the commercial orchard (Table 5) the spatial distribution pattern was characterized as moderately aggregated.. Population growth may occur due to the infestation of the fruits of plants that are used as mating sites by these tephritids, which soon after lay eggs on fruits.

The Poisson and binomial positive distributions do not fit our data because a large number of individuals of *Anastrepha* species was caught in a few traps, indicating a clustered (i.e., clumped) distribution. This finding is in agreement with Martella et al. (2012) for aggregated distributions. Martella et al. (2012) highlighted that the common occurrence of high population densities of individuals in some areas and low densities in others.

We observed that the spatial distribution of fruit fly species was clustered not only in the native forest and backyard orchard, where the fruit trees were randomly arranged, but also in the commercial orchard, where the plants were arranged according to a pre-established density and distribution pattern. The fruit fly spatial distribution pattern remained clustered even when traps were set at different distances. In this study, the traps were spaced more than 100 m away from each other in the forest and less than 50 m away from each other in the backyard and commercial orchards. Silva (2007) captured a higher number of *C. capitata* in traps at 25 and 50 m from the release site, in comparison with traps installed at greater distances. According to Silva (2007), the maximum limit of movement for this fruit flies species was 250 m from the release site.

The clustered distribution observed in the present study might also be influenced by the mating behavior of the fruit fly species. In some *Anastrepha* species, the male performs courtship through a ritual dance, called lekking behavior, in which several males come to a point and release sex pheromone together to attract conspecific females (Facholi-Bendassolli & Uchoa 2006). According toSegura et al. (2007), for *A. fraterculus* the most successful males are those grouped in the region of the tree with the highest luminous intensity in the early hours of the day. The calling behavior with release of sexual pheromone is positively associated with the copulatory success of males, which also correlates with some morphometric and behavioral traits.

CORRELATION WITH WEATHER

The RH and WS, per season of the year, showed an influence on the number of fruit flies caught in the traps. The number of fruit flies per trap per 30 d interval (FFTD) expressed an inverse and significant correlation with WS, and a direct correlation with RH, when the overlap effect is eliminated. Our results agree with those of Chen & Ye (2007). They found that air temperature, precipitation, hours of sunshine, and RH were the main weather factors correlated with changes in population size for *Bactrocera dorsalis* (Hendel).

In this study, the maximum temperature and the accumulated precipitation did not have a significant effect on the capture of fruit flies, i.e., the correlations did not differ from zero. However, the abundance of *Anastrepha* spp. was significantly influenced by lower temperatures (capture go up) compared with higher temperatures (capture go down).

The average maximum RH was positively correlated with FFTD, probably due to the effect of existing multicollinearity with other climatic variables.Possibly the increase in fruit fly abundance in relation to RH was due to the fact that in the sampling period the average RH had a greater amplitude in relation to the minimum and maximum humidity, becoming more favorable to the development of fruit flies. According to Rodrigues (2004), the favorable range of RH for insects is between 40 and 80%, which provides greater development speed, longer longevity, and greater fecundity.

When we analyzed the effect of the correlations individually, without eliminating the overlap effect, WS was the only weather variable that showed a negative and significant correlation with the number of fruit flies caught in the traps (p< 0.05).This finding is in agreement with Chen & Ye (2007), who highlighted that weather conditions, such as temperature, insolation, and WS, could affect the behavior of fruit flies.

**Conclusions**

In the native forest and in the backyard orchard, we found positive correlations between the abundance of fruit flies and the seasons of the year, with higher abundance of flies caught in the winter. In the commercial orchard, higher capture of *Anastrepha* species occurred in the summer. *Anastrepha* species presented a strongly aggregated spatial distribution in the native forest and the backyard orchard, while in the commercial orchard their populations were moderately aggregated. Relative humidity and wind speed influenced the capture of *Anastrepha* species in the traps, with the 2 variables explaining 93.1% of the total variability in fruit fly capture per trap per 30 d interval.

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**Table 1.** Composition of *Anastrepha* species (Diptera: Tephritidae) caught in McPhail traps throughout the year in 3 environments from Dourados region, Mato Grosso do Sul state, Midwest Brazil, Jun 2005 to Jun 2007.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species (♀♀) | Native Forest | | | | Sub Total by species | Backyard Orchard | | | | Sub Total by species | Commercial Orchard | | | | Sub Total by species | All Environments | | | | Total by species | |
| Su | Au | Wi | Sp | Su | Au | Wi | Sp | Su | Au | Wi | Sp | Su | Au | Wi | Sp |
| *Anastrepha amita* Zucchi | 0 | 0 | 2 | 0 | 2a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2n | |
| *A. barnesi* Aldrich | 0 | 0 | 6 | 0 | 6a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6a | |
| *A. daciformis* Bezzi | 0 | 0 | 1 | 6 | 7a | 0 | 0 | 1 | 3 | 4n | 0 | 0 | 0 | 3 | 3a | 0 | 0 | 2 | 12 | 14a | |
| *A. dissimilis* Stone | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1n | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1n | |
| *A. elegans* Blanchard | 0 | 1 | 2 | 4 | 7a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 7a | |
| *\*A.fraterculus* (Wiedemann) | 0 | 5 | 13 | 1 | 19a | 4 | 15 | 145 | 68 | \*232a | 3 | 5 | 2 | 1 | 11a | 7 | 25 | 160 | 70 | \*262b | |
| *A. montei* Lima | 0 | 17 | 7 | 2 | \*26a | 0 | 6 | 114 | 9 | 129b | 0 | 0 | 3 | 0 | 3a | 0 | 23 | 124 | 11 | 158c | |
| *\*A. striata* Schiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 3 | 14c | 0 | 0 | 1 | 1 | 2a | 0 | 0 | 12 | 4 | 16a | |
| *\*A. serpentina* (Wiedemann) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1n | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1n | |
| *\*A. obliqua* (Macquart) | 1 | 0 | 1 | 0 | 2a | 83 | 109 | 362 | 108 | \*662d | 0 | 2 | 1 | 0 | 3a | 84 | 11 | 364 | 108 | \*567d | |
| *\*A. sororcula* Zucchi | 0 | 4 | 25 | 10 | \*39b | 25 | 8 | 102 | 261 | \*396a | 72 | 23 | 0 | 5 | \*100b | 97 | 35 | 127 | 276 | \*535d | |
| *\*A. pseudoparallela* (Loew) | 1 | 3 | 8 | 12 | 24a | 0 | 3 | 39 | 11 | 53bc | 1 | 0 | 0 | 23 | 24a | 2 | 6 | 47 | 46 | 101c | |
| *\*A*. *turpiniae* Stone | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2n | 3 | 0 | 0 | 1 | 4a | 3 | 0 | 1 | 2 | 6n | |
| *\*A*. *zenildae* Zucchi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 4n | 3 | 0 | 0 | 0 | 3a | 3 | 0 | 4 | 0 | 7n | |
| ♀♀ *Anastrepha* species | 2 | 30 | 65 | 35 | 132 | 112 | 141 | 781 | 464 | 1,498 | 82 | 30 | 7 | 34 | 153 | 196a | 201ab | 853c | 533b | 1,783 | |
| ♂♂ *Anastrepha* species | 5 | 42 | 81 | 41 | 169 | 177 | 87 | 650 | 528 | 1,442 | 48 | 47 | 4 | 14 | 113 | 230 | 176 | 735 | 583 | 1,724 | |
| Total *Anastrepha* species | 7a | 72b | 146c | 76b | 301A | 289a | 228a | 1431b | 992c | 2,940B | 130a | 77ab | 11b | 48ab | 266A | 426ab | 377a | 1,588c | 1,116b | 3,507 |

\*Species considered pests; Summer (Su); autumn (Au); winter (Wi), and spring (Sp); ♀♀ = female, ♂♂ = male; Small and equal letters in the same row or column do not differ significantly by Dunn–Bonferroni test (*p*< 0.01); Capital and equal letters in the same row do not differ significantly; n = do not included in the evaluation because they were not dominant.

**Table 2.** Faunistic analysis of the *Anastrepha* species (Diptera: Tephritidae) caught in 3 environments of Dourados region, Mato Grosso do Sul state, Midwest Brazil, Jun 2005 to Jun 2007.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Native Forest | | | | | | Backyard Orchard | | | | | | Commercial Orchard | | | | | | Total | | | | | | |
| NI | NS | Doa | Abb | Frc | Cod | NI | NS | Doa | Abb | Frc | Cod | NI | NS | Doa | Abb | Frc | Cod | NI | NS | Doa | Abb | | Frc | Cod |
| *A. amita* | 4 | 3 | ND | R | FF | Z | 0 | 0 | NA | NA | NA | NA | 0 | 0 | NA | NA | NA | NA | 2 | 2 | ND | | R | FF | Z |
| *A. barnesi* | 12 | 5 | D | D | FF | Z | 0 | 0 | NA | NA | NA | NA | 0 | 0 | NA | NA | NA | NA | 6 | 6 | D | | C | F | Z |
| *A. daciformis* | 14 | 4 | D | C | F | Z | 4 | 3 | ND | C | F | Z | 6 | 2 | D | C | F | Y | 14 | 10 | D | | VA | VF | Z |
| *A. dissimilis* | 0 | 0 | NA | NA | NA | NA | 1 | 1 | ND | C | F | Z | 0 | 0 | NA | NA | NA | NA | 1 | 1 | ND | | R | FF | Z |
| *A. elegans* | 14 | 8 | D | C | F | Y | 0 | 0 | NA | NA | NA | NA | 0 | 0 | NA | NA | NA | NA | 7 | 7 | D | | C | F | Z |
| ***A. fraterculus*** | 38 | 17 | D | C | F | W | \*232 | 31 | SD | SA | SF | W | 11 | 9 | D | C | F | W | \*262 | 126 | SD | | SA | SF | W |
| *A. montei* | \*52 | 16 | D | VA | VF | W | 129 | 17 | SD | SA | SF | Y | 3 | 2 | ND | C | F | Y | 158 | 72 | SD | | SA | SF | Y |
| ***A. striata*** | 0 | 0 | NA | NA | NA | NA | 14 | 7 | D | VA | VF | Y | 2 | 2 | ND | C | F | Y | 16 | 14 | D | | VA | VF | Y |
| ***A. serpentina*** | 0 | 0 | NA | NA | NA | NA | 1 | 1 | ND | C | F | Z | 0 | 0 | NA | NA | NA | NA | 1 | 1 | ND | | R | FF | Z |
| ***A. obliqua*** | 4 | 3 | ND | R | FF | Z | \*662 | 47 | SD | SA | SF | W | 3 | 3 | ND | C | F | Y | \*667 | 189 | SD | | SA | SF | W |
| ***A. sororcula*** | \*78 | 19 | D | VA | VF | W | \*396 | 38 | SD | SA | SF | W | \*100 | 17 | SD | SA | SF | W | \*535 | 174 | SD | | SA | SF | W |
| ***A. pseudoparallela*** | 48 | 15 | D | A | VF | W | 53 | 18 | SD | SA | SF | Y | 24 | 4 | D | VA | VF | Y | 101 | 68 | SD | | SA | SF | Y |
| ***A*. *turpiniae*** | 0 | 0 | NA | NA | NA | NA | 2 | 2 | ND | C | F | Z | 4 | 3 | ND | C | F | Y | 6 | 5 | D | | C | F | Z |
| ***A*. *zenildae*** | 0 | 0 | NA | NA | NA | NA | 4 | 3 | ND | C | F | Z | 3 | 3 | ND | C | F | Y | 7 | 7 | D | | C | F | Z |

NI = number of individuals; NS = number of samples with the species; Do = dominance: Ab = abundance; Fr = frequence, and Co = constance.

aDominance: ND = not dominant (0–1/3 = 33% of the species present); D = dominant (2/3 of the species present); SD = super dominant (1/1 of the species present); NA = not applicable as no individuals collected. bAbundance: R = rare (≈ 0.00–16.67%); D = dispersed (≈16.67–33.34%); C = common (≈33.34–50.00%); A = abundant (≈50.00–66.68%); VA = very abundant (≈66.68–83.35%); SA = super abundant (≈ 83.35–100.00%); NA = not applicable as no individuals collected. cFrequency: FF = infrequent (0–25%); F = frequent (25–50%); VF = very frequent (50–75%); SF = super frequent (75–100%); NA = not applicable as no individuals collected. dConstance: Z = accidental (0–33% or 1/3), species present in less than 25% of the samples; Y = accessory (34–66% or 2/3), species present in 25 to 50% of the samples; W = constant (67–100% or 1/1–3/3), species present in 50% or more of the samples; NA = not applicable as no individuals collected.

Species that are considered pests are in bold; \* = indicator of the environment

**Table 3.** Species of *Anastrepha* (Diptera: Tephritidae) captured in 8 McPhail traps with food bait in a native forest (Dourados, Mato Grosso do Sul state, Midwest Brazil, Jun 2005 to Jun 2007): dispersion index mean variance *I*, factor *K*, and theoretical frequency distributions.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Season | Month | Descriptive Analysis | | Dispersion Index | | Theoretical Distribution of Frequency | | | | | |
| NFF | Average | *I* | *K* | PD | df | NBD | Df | PBD | Df |
| Summer | Jan | 2 | 0.038 | 3.53Ag | 0.015Ag | 0.23u | 0 | 0.54u | -1 | 0.23u | −1 |
| Summer | Feb | 3 | 0.057 | 5.30Ag | 0.013Ag | 0.61u | 0 | 3.81Ag | 1 | 1.41u | −1 |
| Summer | Mar | 9 | 0.170 | 15.90Ag | 0.011Ag | 13.51\*\* | 1 | 2.83Ag | 1 | 13.55u | 0 |
| Autumn | Apr | 17 | 0.321 | 30.03Ag | 0.011Ag | 63.85\* | 2 | 1.04Ag | 1 | 30.38u | 0 |
| Autumn | May | 33 | 0.500 | 72.6Ag | 0.007Ag | 63.19\* | 2 | 5.05u | 0 | 63.58\*\* | 1 |
| Autumn | Jun | 18 | 0.283 | 26.71Ag | 0.011Ag | 26.34\* | 1 | 3.50Ag | 1 | 69.01\*\* | 1 |
| Winter | Jul | 28 | 0.528 | 49.47Ag | 0.011Ag | 69.53\* | 2 | 5.68\* | 1 | 69.94\*\* | 1 |
| Winter | Aug | 165 | 1.887 | 196.64Ag | 0.010Ag | 504.67\*\* | 5 | 12.62\*\* | 2 | 504.56\*\* | 4 |
| Winter | Sep | 41 | 0.641 | 60.47Ag | 0.011Ag | 86.48\*\* | 2 | 2.31Ag | 2 | 87.10\*\* | 1 |
| Spring | Oct | 20 | 0.340 | 31.95Ag | 0.011Ag | 34.36\*\* | 1 | 0.50Ag | 1 | 115.30\*\* | 1 |
| Spring | Nov | 24 | 0.453 | 42.40Ag | 0.011Ag | 57.76\*\* | 2 | 4.32Ag | 2 | 56.61\*\* | 1 |
| Spring | Dec | 21 | 0.340 | 31.91Ag | 0.011Ag | 29.79\*\* | 1 | 1.57Ag | 1 | 30.01u | 0 |

NFF = number of fruit flies; *I* = variance-to-mean ratio index; k = exponent of the negative binomial distribution; PD = Poisson distribution; df = degrees of freedom of the χ2 distribution; NBD = negative binomial distribution; PBD = positive binomial distribution;

Ag = aggregated; u = undetermined; \*\* highly significant (*P* < 0.01), \* significant (*P* < 0.05).

**Table 4.** Average number of fruit flies by species in the genus *Anastrepha* (Diptera: Tephritidae), captured in 8 McPhail traps with food bait in a backyard orchard in Dourados, Mato Grosso do Sul state, Midwest Brazil, Jun 2005 to Jun 2007: dispersion index mean variance *I*, factor k, and theoretical frequency distributions (i.e., Poisson, negative binomial, and positive binomial).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Season | Month | Descriptive Analysis | | Dispersion Index | | Theoretical Distribution of Frequency | | | | | |
| NFF | Average | *I* | *K* | PD | df | NBD | Df | PBD | Df |
| Summer | Jan | 89 | 1.679 | 21.34Ag | 0.082Ag | 175.56\*\* | 4 | 9.20Ag | 6 | 198.15\*\* | 3 |
| Summer | Feb | 76 | 1.434 | 18.52Ag | 0.082Ag | 163.42\*\* | 3 | 14.77\* | 5 | 146.32\*\* | 2 |
| Summer | Mar | 264 | 4.981 | 80.63Ag | 0.062Ag | 6,397.63\*\* | 9 | 11.39Ag | 7 | 1,217.26\*\* | 7 |
| Autumn | Apr | 116 | 2.189 | 36.22Ag | 0.062Ag | 347.48\*\* | 5 | 8.88Ag | 5 | 367.49\*\* | 4 |
| Autumn | May | 78 | 1.472 | 24.67Ag | 0.062Ag | 142.36\*\* | 3 | 6.47Ag | 3 | 145.60\*\* | 2 |
| Autumn | Jun | 294 | 5.547 | 89.70Ag | 0.062Ag | 11,090.92\*\* | 10 | 11.41Ag | 7 | 15,209.13\*\* | 9 |
| Winter | Jul | 338 | 6.377 | 91.40Ag | 0.070Ag | 1,489.29\*\* | 2 | 18.49\* | 8 | 32,630.96\*\* | 10 |
| Winter | Aug | 517 | 9.755 | 102.24Ag | 0.096Ag | 1,181.03\*\* | 11 | 21.83\* | 8 | 1,651.12\*\* | 10 |
| Winter | Sep | 642 | 12.113 | 158.19Ag | 0.077Ag | 2,295.46\*\* | 13 | 23.85\* | 11 | 1,657.30\*\* | 11 |
| Spring | Oct | 352 | 6.641 | 181.48Ag | 0.037Ag | 1,168.50\*\* | 9 | 8.84Ag | 6 | 1,437.91\*\* | 8 |
| Spring | Nov | 345 | 6.509 | 132.70Ag | 0.049Ag | 949.01\*\* | 9 | 9.45Ag | 7 | 1,233.07\*\* | 8 |
| Spring | Dec | 205 | 3.868 | 63.10Ag | 0.062Ag | 2,121.29\*\* | 7 | 11.11Ag | 6 | 2,469.19\*\* | 6 |

NFF = number of fruit flies; *I* = variance-to-mean ratio index; *K*= exponent of the negative binomial distribution; PD = Poisson distribution; df = degrees of freedom of the χ2 distribution; NBD = negative binomial distribution; PBD = positive binomial distribution;

Ag = aggregated; \*\* highly significant (*P* < 0.01), \* significant (*P* < 0.05).

**Table 5.** Average number of fruit flies by species in the genus *Anastrepha* (Diptera: Tephritidae), captured in 10 McPhail traps with food bait in a commercial orchard in Dourados, Mato Grosso do Sul state, Midwest Brazil, Jun 2005 to Jun 2007: dispersion index mean variance (*I*), factor *K*, and theoretical frequency distributions (i.e., Poisson, negative binomial, and positive binomial).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Season | Month | Descriptive Analysis | | Dispersion Index | | Theoretical Distribution of Frequency | | | | | |
| NFF | Average | *I* | *K* | PD | Df | NBD | Df | PBD | df |
| Summer | Jan | 11 | 0.104 | 4.94Ag | 0.026Ag | 3.96u | 0 | 0.09u | 0 | 4.42u | −1 |
| Summer | Feb | 3 | 0.028 | 0.98Ag | −1.486Un | 0.00 u | 0 | 0.01u | 0 | 0.00u | −1 |
| Summer | Mar | 126 | 1.189 | 36.10Ag | 0.034Ag | 193.98\*\* | 3 | 5.95Ag | 6 | 196.36\*\* | 2 |
| Autumn | Apr | 100 | 0.943 | 37.51Ag | 0.026Ag | 146.8\*\* | 3 | 5.27Ag | 5 | 144.44\*\* | 1 |
| Autumn | May | 18 | 0.170 | 6.33Ag | 0.032Ag | 17.28\*\* | 1 | 2.96Ag | 2 | 17.04u | 0 |
| Autumn | Jun | 4 | 0.038 | 1.48Ag | 0.079Ag | 0.23u | 0 | 0.02u | −1 | 0.23u | −1 |
| Winter | Jul | 4 | 0.038 | 1.48Ag | 0.079Ag | 0.23u | 0 | 0.02u | −1 | 0.23u | −1 |
| Winter | Aug | 5 | 0.047 | 1.77Ag | 0.061Ag | 0.76u | 0 | 0.12u | −1 | 0.76u | −1 |
| Winter | Sep | 2 | 0.019 | 0.99Ag | −1.981Un | 0.00u | 0 | 0.00u | −1 | 0.00u | −1 |
| Spring | Oct | 5 | 0.047 | 2.17Ag | 0.040Ag | 0.76u | 0 | 0.03u | 0 | 0.76u | −1 |
| Spring | Nov | 5 | 0.047 | 1.36Ag | 0.130Ag | 0.13u | 0 | 0.01u | −1 | 0.17u | −1 |
| Spring | Dec | 107 | 1.009 | 55.64Ag | 0.018Ag | 172.98\*\* | 3 | 6.66Ag | 3 | 185.06\*\* | 2 |

NFF = number of fruit flies; *I* = variance-to-mean ratio index; *K* = exponent of the negative binomial distribution; PD = Poisson distribution; df = degrees of freedom of the χ2 distribution; NBD = negative binomial distribution; PBD = positive binomial distribution;

Ag = aggregated; Un = uniform; u = undetermined; \*\* highly significant (*P* < 0.01).

**Table 6.** Multiple regression of the number of fruit flies by species of the genus *Anastrepha* (Diptera: Tephritidae), captured in McPhail traps per day (FFTD), and its relationship with relative humidity and wind speed in 3 environments of the Dourados region, Mato Grosso do Sul state, Midwest Brazil (Jun 2005 to Jun 2007)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | Confidence Interval of 95% for B and R² values | | | |
| *B* (DE) | Lower | Upper | R² |
| Constant (FFTD) | 60.304 (5.770) \*\* | 48.290 | 72.319 | 0.931 |
| Relative humidity (%) | 0.742 (0.060) \*\* | 0.618 | 0.866 | 0.666 |
| Wind speed (m/s) | −5.754 (1.484) \*\* | −8.839 | −2.669 | −0.064 |

*B* = angular slope constant; DE = default error;

ANOVA *F*2,21 = 141,184; (FFTD) = 60.304 + 0.742RH − 5.754WS; *t* test (*p* < 0.001).

FFTD = fruit flies per trap per day; RH = relative humidity; WS = wind speed; highly significant (*p* < 0.01).