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Population Dynamics of the Cassava Shoot Fly *Neosilba perezi* (Diptera: Lonchaeidae) in Organic Fields of the Brazilian Cerrado

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ABSTRACT

The shoot-mining fly *Neosilba perezi* (Diptera: Lonchaeidae) severely limits stem cutting production in cassava, yet its population ecology in tropical dry savannas is poorly documented. We monitored two contiguous 0.20 ha organic cassava fields in the Brazilian Cerrado monthly for 17 months (March 2017 - July 2018), visually inspecting every plant at each visit (34 site-months; 85,000 shoots). Mean infestation was 13.3 %, but prevalence climbed to 45 % at the onset of the dry, cool season. A quasi-binomial generalised linear model revealed a strong quadratic response to 14-day mean temperature, with maximal infestation predicted at 28 °C, and a weaker negative association with cumulative rainfall. Field identity explained < 3 % of the deviance, indicating homogeneous pressure at the landscape scale. The resulting 28 °C / low-rainfall threshold delineates a June-August surveillance window in which early trap sampling can guide selective interventions in pesticide-restricted systems. These baseline parameters extend the biogeographical range of quantified *N. perezi* outbreaks and provide input for phenology models that anticipate pest pressure under future warming scenarios.

Keywords: phenology modelling, shoot-mining fly, organic agroecosystems, savanna climate, temperature optimum, sustainable pest management.

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INTRODUCTION

Cassava, *Manihot esculenta* Crantz, occupies > 30 million ha worldwide and underpins the food security of roughly 800 million people (FAOSTAT 2023). In Brazil, certified-organic plantings already exceed 55 000 ha-concentrated in the Midwestern Cerrado savanna where favourable winter prices and low-input systems prevail (MAPA 2024). Because cassava is vegetatively propagated, the exposed apical buds are chronically vulnerable to herbivores. A key pest is the shoot-mining fly *Neosilba perezi* (Romero & Ruppel 1973) (Diptera: Lonchaeidae); larval tunnelling arrests apical growth, induces excessive branching and can cut stake yield by up to 25 % (Hershey, 1987; Androcioli et al., 2019, 2022).

On cassava, *Neosilba perezi* females oviposit on the apical meristem. Larvae mine the shoot tip, producing a honey-colored exudate and necrosis; vertical growth is arrested, the plant responds with compensatory branching, and the number of marketable stakes is reduced. In severe attacks the main stem is lost and harvest is delayed (Bellotti, 1999; Lourenção, 1996; Gisloti, 2011; Gisloti, 2013; Androcioli et al., 2019).

The genus *Neosilba* comprises > 40 Neotropical species with broad host ranges (Galeano-Olaya & Canal, 2012; Bomfim, Gisloti, & Uchôa, 2014; Calvo, Delgado, Scatoni, & Garcia, 2017). Formerly misidentified as *Lonchaea pendula*, *N. perezi* has been recorded from Florida to the Amazon Basin (Waddill & Weems, 1978; Lemos et al., 2015); within Brazil, reports cluster in the Southeast and Northeast (Lourenção, Lorenzi,& Ambrosano, 1996; Gisloti & Prado, 2011, 2012, 2013). Consequently, the rapidly expanding organic-cassava belt of the Cerrado remains virtually unstudied.

Temperature and rainfall drive development and voltinism in Tephritoidea and allied dipterans (Aluja & Mangan, 2008). Regional climate projections forecast a 1.5-2 °C rise by mid-century (IPCC 2021), emphasising the need for quantitative thresholds in Lonchaeidae phenology. Preliminary laboratory assays suggest optimum larval development of *N. perezi* near 22-24 °C (Androcioli et al., 2022).

Despite the rapid expansion of certified-organic cassava in the Cerrado-already > 55 000 ha according to the Brazilian Ministry of Agriculture (MAPA 2024)-no quantitative study has yet addressed *N. perezi* in this biome.

We hypothesised that field infestation would follow a nonlinear response to 14-day mean temperature, peaking close to 23-24 °C and falling off under both cooler (< 18 °C) and hotter (> 30 °C) regimes, with rainfall acting as a secondary modifier. To test this, we conducted a 17-month survey (March 2017 - July 2018) in two adjacent organic cassava plots in Midwestern Brazil. Our specific aims were to (i) characterise seasonal fluctuations in larval prevalence and (ii) quantify the temperature and precipitation ranges that best explain those fluctuations.

By delimiting a calendar window for early detection, the study seeks to refine selective interventions in pesticide-restricted systems and to supply baseline parameters for predictive phenology models under future warming scenarios. Despite records from the Southeast and Amazon, the organic cassava belt of the Brazilian Cerrado remains poorly documented regarding seasonality and climatic windows of risk.

MATERIALS AND METHODS

Study area

Field work was conducted between March 2017 and July 2018 in two pesticide-free cassava plots managed by smallholders in Caarapó, Mato Grosso do Sul, Brazil. The fields are 1.4 km apart on the western shoulder of highway MS-156 (Site 1: 22.644 377 ° S, 54.838 522 ° W, 460 m a.s.l.; Site 2: 22.631 620 ° S, 54.848 535 ° W, 458 m a.s.l.). The region lies in a transition from humid subtropical (Cfa) to tropical savanna (Aw) climates, with 30-yr means of 23 °C and 1 500 mm annual rainfall. Both sites overlie dystrophic Red Latosols sensu SiBCS (Berezuk, Silva, Lamoso, & Schneider, 2017).

Cassava cultivation and sampling design

Both fields were managed under certified organic practices. No synthetic fertilizers or pesticides were applied, and the crop was strictly rain-fed (no irrigation). Weed control was manual. The cultivar IAC 576-70 was planted at 1.0 m × 0.80 m. Subplots (0.20 ha) were fixed and surveyed throughout the crop cycle.

Infestation assessment

From 60 DAP to harvest (≈ 250 DAP) all plants in each subplot were inspected monthly. A plant was recorded as infested when its apical shoot showed the characteristic yellow exudate and necrosis produced by *Neosilba perezi* larvae. Symptomatic shoots were tagged with 4-mm UV-stable plastic rings and excised at the following visit to prevent double counting. Each month, 30 tagged shoots per site were dissected; larval confirmation exceeded 95 %.

For each visit and site we recorded the exact number of live plants inspected (denominator) and the number of symptomatic apices (numerator). Exact denominators by date and site are provided in Table S1 and were used in all prevalence calculations. No approximate counts or rounded denominators were used in the analyses.

Climate data

Daily mean temperature and precipitation were obtained from the INMET automatic station Caarapó-A746, located 6 km from the plots. For every sampling date we calculated 14-day mean temperature and 14-day cumulative rainfall-windows chosen a priori from laboratory development times of *N. perezi*.

Statistical analysis

Infestation prevalence (successes = infested plants; failures = total − infested) was modelled with a quasi-binomial generalised linear model (logit link) in R v4.3.2 (R Core Team 2024). Predictors were 14-day mean temperature (linear and quadratic terms), 14-day rainfall and site (factor). Overdispersion was evaluated with the Pearson χ^2/df statistic ($\hat{c} = 3.56$) and quasi-likelihood-corrected standard errors were used throughout. Durbin-Watson tests on Pearson residuals detected no temporal autocorrelation ($P > 0.10$). Model coefficients are reported as $\beta \pm SE$ with 95 % confidence intervals; statistical significance was set at $\alpha = 0.05$.

Specimen deposition and permits

Voucher adults and larvae of *N. perezi* (codes NP-UFGD 001-100) are deposited in the Entomological Collection of the Universidade Federal da Grande Dourados. Specimens were identified with the paper of Gisloti & Prado (2013) and verified by Dr L. J. Gisloti. Field activities were authorised by SISBIO licence 43748 and carried out with land-owner consent.

RESULTS

Overall prevalence and site comparison

Across 34 site-by-month observations we inspected 85,000 shoot apices in total; the exact counts per site and date are listed in Table S1. Mean prevalence was 13.3 ± 2.6 % (SE). The quasi-binomial GLM detected a small but significant site effect (Site 2 lower than Site 1), but 'site' accounted for < 3 % of explained deviance.

Seasonal pattern

Three clear peaks were evident in 2017-June, August, and October-with site-specific differences in August (Fig. 1). In 2018, prevalence remained near zero through late autumn/early winter and rose only in July-September. The 14-day climate context (Fig. 2) shows warmer means and more frequent short rainfall pulses in May-August 2018 than in the same period of 2017.

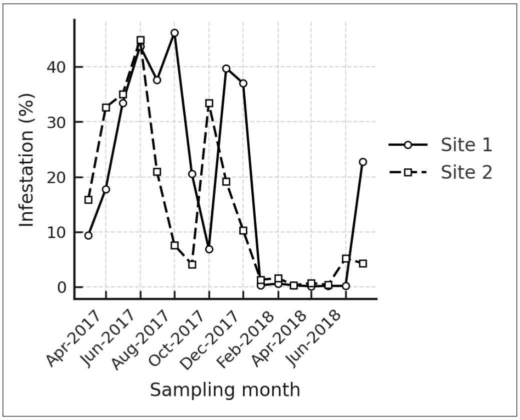


Figure 1. Monthly prevalence of *Neosilba perezi* in two organic cassava fields. Solid line with circles, Site 1; dashed line with squares, Site 2. Points = monthly site values; error bars omitted for clarity.

Interannual contrast

Patterns differed between years. In 2017, prevalence rose rapidly in the cool-dry months, with pronounced peaks in June, August and October (Fig. 1). In 2018, values remained near zero through late autumn and early winter and only increased in July-September. The 14-day climate context helps explain this contrast: during May-August 2018, mean temperature over 14 days was generally higher and short rainfall pulses more frequent than in the same period of 2017 (Fig. 2). These conditions are consistent with the low odds of infestation at the warmer end of the thermal window captured by our model.

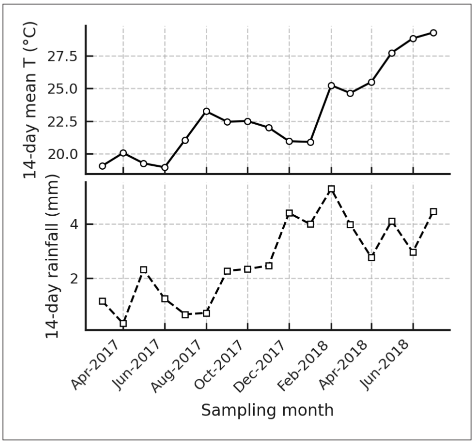
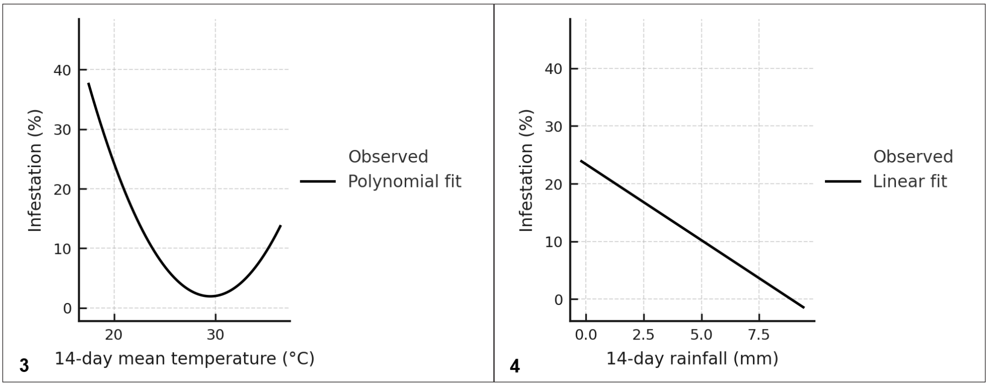


Figure 2. Climate context during the survey. Top: 14-day mean temperature. Bottom: 14-day cumulative rainfall. Values are means across the two fields on each sampling date.

Climatic drivers

The GLM with 14-day mean temperature (linear and quadratic terms) and 14-day rainfall explained 35.7 % of deviance ($\hat{c}$ = 3.56). Temperature showed a hump-shaped relation, with low odds below ~18 °C and above ~30 °C; rainfall had a modest negative effect. For visual reference, Figures 3-4 show simple polynomial (temperature) and linear (rainfall) fits to the pooled observations; these curves are illustrative and are not the quasi-binomial GLM predictions.



Figures 3-4 Infestation versus 14-day mean temperature and cumulative rainfall. 3) Points = site-by-date observations. Black curve = second-degree polynomial fit to all observations (visual aid consistent with the GLM direction); not the GLM curve; 4) Points = site-by-date observations. Black line = simple linear fit to all observations (visual aid consistent with the GLM direction); not the GLM curve.

DISCUSSION

This study is the first to quantify the phenology of *N. perezi* in organic cassava fields of the Cerrado savanna, confirming the fly as a resident pest in Midwestern Brazil and extending earlier reports from the Southeast and North (Lourenção et al., 1996; Gisloti & Prado, 2013; Lemos et al., 2015).

Regional damage and biology

Reports from other Brazilian regions describe reductions in the number of marketable stakes and delayed harvest under shoot-fly attack, consistent with our field observations (Lourenção, 1996; Gisloti, 2011; Bellotti, 1999). Females lay eggs on the apical meristem; larvae mine the shoot; pupation occurs in the soil near the plant (Gisloti, 2013). These life-history traits help explain abrupt increases in prevalence when cool-dry conditions coincide with abundant young shoots.

Interannual dynamics, climate windows, and survey length

The weaker mid-year signal in 2018 relative to 2017 (Figs. 1-2) suggests modulation by short thermal sequences and brief rainfall windows. Light rains may wash eggs from exposed shoot tips and alter near-surface soil moisture for pupal emergence, mechanisms documented for fruit-associated dipterans and worth testing for lonchaeids in cassava (Aluja & Mangan, 2008). The dynamics of tropical fruit flies also show that short surveys may miss pulses tied to resource phenology and climate windows (Ordano et al., 2013). Multi-year monitoring is therefore advisable in organic, rain-fed systems.

Seasonal pattern

Three infestation peaks-June, August and October-occurred during the cool-dry season, contrasting with post-rainy peaks reported for humid-subtropical São Paulo (Gisloti & Prado, 2011). Our field optimum sits within a subtropical thermal window consistent with reports for related fruit-associated dipterans; however, the physiological mechanisms underlying the midsummer trough remain to be verified under controlled conditions.

Climatic drivers

The quasi-binomial model confirmed a nonlinear temperature response and a secondary, negative rainfall effect. The rainfall trend is displayed as a simple linear fit (Fig. 3) because adding a quadratic term did not improve the model ($\Delta AIC > 2$), whereas the quasi-binomial GLM remained the best descriptor for temperature.

This contrasts with the positive rainfall-infestation correlation observed by Lourenção et al. (1996), possibly because their study used monthly rainfall totals in a wetter climate, whereas short convective showers characteristic of the Cerrado may wash eggs from shoot tips. Similar rainfall-mediated egg loss has been reported in Tephritidae (Aluja & Mangan, 2008). Despite explaining 36 % of the deviance, the moderate over-dispersion ($\hat{c} = 3.56$) implies unmeasured factors-shoot age, canopy micro-humidity, natural enemies-still influence prevalence.

Management implications

Management implications in rain-fed, organic cassava. Concentrating scouting between June and August-or whenever 14-day means fall into 18-23 °C-can intercept the first cohort. Weekly apex inspections and discreet sticky cards in this window support selective pruning and biological control before exponential growth. The weak site effect suggests recommendations are transferable across neighboring farms.

Limitations and future directions

The dataset covers a single crop cycle at two adjacent sites; multi-year, multi-altitude studies are needed to refine the climatic envelope. Future work should quantify egg-laying preferences, microclimatic humidity and parasitism rates to reduce model dispersion. Integrating degree-day models with gridded rainfall data may improve early-warning systems under the projected 1.5-2 °C regional warming (IPCC, 2021).

CONCLUSION

Outbreaks of *N. perezi* in Midwestern organic cassava are driven chiefly by temperature, with rainfall exerting a secondary negative influence. Timely surveillance during the cool-dry season can optimise intervention timing and minimise stake losses in pesticide-restricted systems.

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DATA AVAILABILITY

The full dataset and R scripts used for the analyses are deposited in Zenodo (Doi. 10.5281/zenodo.16176451) and are freely available under a CC-BY licence.

AUTHOR CONTRIBUTIONS (CRediT)

Conceptualisation, L.J. Gisloti and M.S.S. Pinto; Methodology, L.J. Gisloti and M.S.S. Pinto; Investigation and data curation, M.S.S. Pinto; formal analysis, L.J. Gisloti and M.S.S. Pinto; Writing - original draft, M.S.S. Pinto; Writing - review & editing, L.J. Gisloti; Funding acquisition, Project administration and Supervision, L.J. Gisloti. All authors approved the final manuscript.

ETHICS STATEMENT

No studies involving vertebrates or human participants were conducted; therefore, ethical approval was not required.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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