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Scientific Note

Comparison of sampling methods for estimating thrips populations in onion crops

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Abstract. Accurate sampling is crucial for managing onion thrips. We evaluated three field techniques: tapping method, bagging method, and blue sticky trap, against direct counting as the reference standard in 30 fields. Assessment integrated relative variance (RV), economic precision (EP), cost, time, and correlation with absolute density. The blue sticky trap was the only method with adequate precision (RV=5.27%) and highest EP (135.50). Although the bagging method was cheapest per sample, the blue sticky trap offered the best field cost-benefit ($3.64/ha) and strongest correlation (R^2=0.79), establishing it as the most reliable tool for IPM monitoring.

Keywords: sampling, insect trap, Thysanoptera, *Allium cepa,* Alliaceae.

Onion (*Allium cepa* L.) is one of the most widely cultivated vegetables in the world, with high economic value, especially in tropical and subtropical regions. The productivity of this crop is strongly limited by the onion thrips, *Thrips tabaci* (Lindeman, 1889) (Thysanoptera: Thripidae), a pest that causes direct damage to leaves and bulbs, reducing both the quantity and the commercial quality of production (Gagnon et al. 2024). Severe infestations can result in losses ranging from 30 to 60%, in addition to favoring the transmission of phytopathogenic viruses and acting as a synergistic effect on the development of onion purple blotch, *Alternaria porri* (Ellis.) Cif. (Saini et al. 2024).

In the context of Integrated Pest Management (IPM), population monitoring is considered one of the essential strategies for precise and economical control interventions (Bueno et al. 2021). Correctly estimating pest density allows the comparison of population levels with economic damage thresholds and determines the appropriate timing for chemical control, avoiding unnecessary insecticide applications that increase costs and promote resistance. Effective monitoring also contributes to reducing environmental impacts and preserving beneficial organisms present in the crop, integrating chemical, biological, and cultural management decisions (Angon et al. 2023).

In addition to providing information for decision-making, continuous monitoring allows the evaluation of the effectiveness of implemented management measures, the identification of spatial and temporal variations in pest populations, and the anticipation of outbreaks before significant economic damage occurs (Silva et al. 2021; Soto-Rojas et al. 2021). Recent studies have shown that monitoring systems based on representative sampling significantly increase the accuracy of decisions, enabling producers to adopt more sustainable and economically viable practices (Iglesias et al. 2021; Komondy et al. 2024).

Therefore, population monitoring emerges as a critical tool for the effective management of *T. tabaci* in onion crops. Although several sampling methods for thrips have been described in the literature, their comparative performance in terms of precision, representativeness, cost, and sampling time has not been adequately evaluated under commercial onion production conditions. Thus, the objective of this study is to evaluate different thrips sampling techniques in onion crops and to select the most appropriate method based on precision, representativeness, economic cost, and sampling time under commercial onion production conditions.

This study was conducted in 30 commercial onion fields (cv. Andromeda) during the 2018 crop season in the Alto Paranaíba region, Minas Gerais. Fields were selected based on area and visible thrips infestation. The regional climate is Cwa (Köppen–Geiger), characterized by a humid subtropical climate with dry winters and hot summers (Santos et al. 2021). Annual precipitation ranges from 1,130 to 1,835 mm and temperatures from 23 to 32 °C.

The sampling techniques used were: direct counting, tapping method, bagging method, and blue sticky trap (Fig. 1). The direct counting technique consisted of opening the central sheaths, carefully closing the tubular leaves and counting the number of thrips on the sheaths and along the leaf directly in the field using a handheld magnifying lens (60×). In the tapping method, onion leaves were vigorously beaten by hand, causing thrips to fall onto a white plastic tray (40 x 30 x 5 cm) positioned beneath the plants, where individuals were counted immediately in the field. In the bagging method, the entire plant was enclosed in a plastic bag, and the plant was cut at the base; thrips were subsequently counted under a stereoscopic microscope in the laboratory. For the blue sticky trap, adhesive cards were used, (15 x 10 cm), installed at a height of 40 cm above the soil, attached to a galvanized wire and placed on a stake of wood (50 x 2.5 x 4.0 cm). Thrips on both adhesive faces were counted weekly.

A standardized sampling pattern was used in all fields. Each sample unit consisted of three plants, with all leaves evaluated. Between 63 and 77 samples were collected per technique during the early bulbification stage (plants with 5–7 leaves). To calculate the number of samples was used a negative binomial distribution model. Was determined to each field one common K (kc= 1.887) at levels of precision error equal to 25%, as determined by Young & Young (2002). Sampling occurred over two months (February–March) to standardize phenological stage and climatic conditions. For the tapping and bagging methods, the time per sample was recorded with a stopwatch (from plant handling to counting completion), and the mean ± SD was calculated from all replicates.

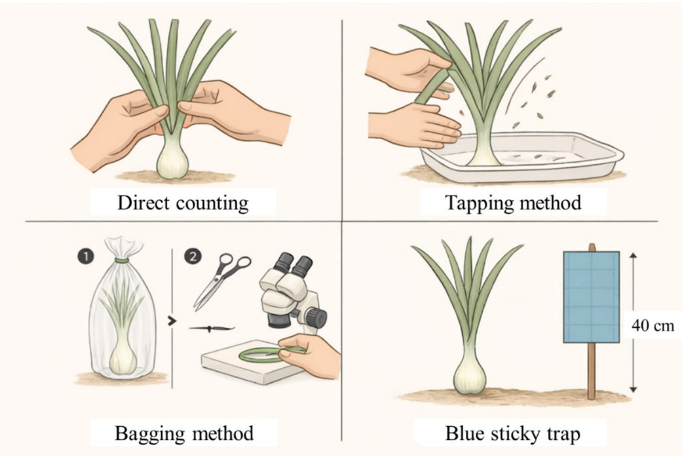

Figure 1. Schematic representation of the four sampling techniques for thrips in onion crops.

Thrips specimens collected by direct counting, tapping method and bagging method were preserved in 70% ethanol and identified to species level using morphological characters under a stereoscopic microscope, following standard taxonomic keys for Thysanoptera. Species identification was confirmed by a specialist, Dr. Élison Fabrício Bezerra Lima (Universidade Federal do Piauí – UFPI, Campus Amílcar Ferreira Sobral). Species frequency (*Freq*) was calculated separately for each sampling technique using the formula (Eq. 1):

$$Freq = (\frac{ni}{n}) \times 100$$

Where *ni* is the number of individuals of species i and N is the total number of thrips individuals collected by each sampling technique.

The sampling techniques were evaluated based on relative variance (*RV*), economic precision (*EP*), sampling cost, and sampling time (Podoler & Rogers 1975; Southwood 1978; Bacci et al. 2006). Representativeness was assessed by linear regression analyses between absolute thrips density per plant, obtained by direct counting on the entire plant, and relative density estimated by tapping method, bagging method, and blue sticky trap. Techniques showing significant correlations ($p < 0.05$), higher regression slopes, and higher coefficients of determination (R^2) were considered more representative. Precision was defined by relative variance (*RV*) and sampling units with RV values equal to or lower than 25% (Eq. 2) were considered acceptable (Southwood 1978; Naranjo & Castle 2010).

$$RV = \frac{(100 \times SE)}{\bar{x}}$$

Where *RV* = relative variance; *SE* = standard error of the mean; $\bar{x}$ = mean.

To integrate precision and economic cost into a single metric for technique comparison, the Economic Precision (*EP*) index was calculated as follows:

$$EP = \frac{100}{RV \times C}$$

Where *RV* is the relative variance (expressed as a percentage) and *C* is the total operational cost per sample (expressed in USD). The cost (C) included: (1) labor, based on the time for field and laboratory work; (2) consumables specific to each technique (e.g., bags, trays, adhesive cards); and (3) field transportation. Equipment depreciation and institutional overhead were excluded. Higher EP values indicate greater cost-effectiveness and precision. This index complemented the evaluations based on *RV*, sampling cost, and sampling time for an integrated efficiency comparison (Kogan & Herzog 1980).

Sampling time was evaluated as the time required to collect each sampling unit. Among the sampling techniques previously identified as representative and precise, those requiring fewer leaves per sample were considered faster, since sampling time increased with the number of leaves evaluated (Bacci et al. 2006).

Response variables were relative variance (RV), economic precision (EP), sampling cost, and sampling time. Density was expressed as insects/100 plants for plant-based methods and insects/trap for the blue sticky trap. Data met ANOVA assumptions (Shapiro-Wilk, Levene's/Bartlett's tests). Differences among techniques were analyzed by ANOVA and Tukey's test ($p < 0.05$). Linear regression assessed the relationship between estimated and absolute densities. All analyses used R software (v.4.3.2) (R Core Team 2023).

Three thrips species were recorded in the sampled onion fields: *T. tabaci*, *Frankliniella occidentalis* (Pergande, 1895), and *Frankliniella schultzei* (Trybon, 1910) (Thysanoptera: Thripidae). The relative frequency of each species varied considerably among sampling techniques, revealing a distinct method-specific selectivity (Tab. 1). The direct counting method, used as the absolute density reference, was strongly dominated by the key pest *T. tabaci* (89.4%), validating it as a reliable standard for this species. In stark contrast, the indirect tapping and bagging methods were selective for *Frankliniella* spp., which together accounted for over 85% of their catches. This demonstrates their inadequacy for estimating *T. tabaci* populations. The species composition on blue sticky traps was not identified, a limitation of this study. However, given the dominance of *T. tabaci* on the plants, the trap's high correlation with total plant density ($R^2 = 0.79$) positions it as a reliable indicator of overall thrips pressure in the field, pressure that is driven by this key pest.

Table 1. Relative frequency (%) of thrips species (*Thrips tabaci* (Lindeman, 1889); *Frankliniella occidentalis* (Pergande, 1895); and *Frankliniella* schultzei (Trybon, 1910) (Thysanoptera: Thripidae)) recorded in onion fields using direct counting, tapping method, and bagging method.

Technique	Frequency (%)		
	Thrips tabaci	***F. occidentalis***	***F. schultzei***
Direct counting	89.40	6.42	4.18
Tapping method	12.90	50.96	36.14
Bagging method	25.36	34.50	40.14

When considering relative variance (RV) and economic precision (EP), only the blue sticky trap technique was adequate for sampling thrips (RV = 5.27% and EP = 135.50). In terms of cost, the bagging method was the least expensive ($0.08 USD per sample), whereas the tapping method required the shortest sampling time (10.16 s per sample) (Tab. 2). The number of samples per hectare for each method was also calculated, with the bagging method requiring the most samples per hectare (60.14), followed by direct counting (43.25) and the tapping method (35.20). The cost per hectare was as follows:

Table 2. Number of samples per hectare, relative variance (RV), economic precision (EP), sampling cost, sampling time, and cost per hectare of different thrips monitoring methods in onion field.

Technique	$\bar{x}$	SE[1]	Number of samples/ha	Relative variance (%)	Economic Precision	Sampling cost (USD)	Sampling time (seconds per sample)	Cost/ha (USD)[2]
Tapping method	28.35	12.42	35.20±6.25	43.81±4.82	8.15±1.12c	0.28±0.01b	10.16±0.50d	9.86±0.06
Direct counting	2.87	0.75	43.25±2.01	26.16±1.58	4.90±0.11d	0.78±0.01a	17.49±0.31c	33.74±0.02
Bagging method	1.65	0.51	60.14±5.34	30.77±2.68	40.63±0.25b	0.08±0.00d	94.45±2.35a	4.81±0.00
Blue sticky trap	2.58	0.14	0.10±0.00	5.27±0.41	135.50±6.47a	0.14±0.01c	61.94±5.44b	3.64±0.00

[1]SE=Standart error; [2]Cost/ha (USD) = Sampling cost (USD) × Number of samples/ha. Means followed by the same letter in the column do not differ from each other (P < 0.05; Tukey test).

the bagging method incurred the highest cost ($4.81), whereas the blue sticky trap showed lower costs ($3.64), while the tapping method presented intermediate costs ($9.86). Although all plots were standardized for cultivar, age, soil, and environmental conditions, field data naturally exhibit variability; the relatively low RV for the blue sticky trap indicates limited variation among the plots, supporting the reliability of this method.

The slopes of the regression curves relating the densities of thrips obtained by each sampling technique to the absolute density per plant (obtained by the direct counting method) differed significantly ($p < 0.05$). The regression curve of the blue sticky trap exhibited the highest slope (S = 0.82) and the highest coefficient of determination ($R^2 = 0.79$), indicating the strongest correlation with thrips densities on the plant (Tab. 3).

The high correlation of the blue sticky trap with absolute plant density (dominated by *T. tabaci*) confirms it as the most reliable method, consistent with findings in tomato and roses (Pizzol et al. 2010; Zulkifli et al. 2024). This supports chromatic attractiveness as a robust monitoring tool across crops. For practical use, the method requires calibration with economic thresholds, such as the 30 Cumulative Insect Days for onion (Kang et al. 2011), for which our data provide the necessary basis. In contrast, the low correlation of indirect methods (tapping, bagging) limits their utility in precision IPM and sequential sampling (Komondy et al. 2024), where accurate timing is critical for the success of alternative or integrated control tactics (Kumar et al. 2022). Thus, sampling method choice dictates the feasibility of the entire management scheme.

The bagging method, although more economical ($0.08 USD per sample), showed no correlation with the absolute plant density (S = 0.00 and $R^2 = 0.08$), limiting its applicability for precise estimates. Indirect methods, such as the tapping method and bagging method, capture only a fraction of the actual population and are more prone to underestimation, especially at low densities, as demonstrated in sequential and binomial sampling plans for *T. tabaci* (Soto-Rojas et al. 2021). The tapping method, although faster (10.16 s per sample), showed moderate correlation with absolute plant density (S = 0.22 and $R^2 = 0.64$), being useful for preliminary assessments. However, as with other indirect methods, its ability to accurately estimate *T. tabaci* populations is limited, particularly at low densities.

Direct counting, although more accurate, required greater time and cost, highlighting the classic trade-off between precision and operational efficiency. The use of precise methods is essential, given that *T. tabaci* can cause significant losses even at low densities (Marullo et al. 2021).

The importance of adequate monitoring is evident in the prevention of outbreaks and the implementation of Integrated Pest Management (IPM) strategies. Recent studies reinforce that integrating biological, cultural, and chemical methods increases the efficiency of thrips management in onion crops (Iglesias et al. 2021; Angon et al. 2023; Gagnon et al. 2024; Saini et al. 2024). Thus, the selection of a sampling method should consider specific objectives, crop characteristics, target species, and available resources (Silva et al. 2021).

In summary, the results indicate that the blue sticky trap is the most suitable technique for regular monitoring of thrips infestations in onion crops. Given the dominance of *T. tabaci* in the plant counts (89.4%), this trap provides a reliable and cost-effective indicator of the field infestation pressure driven by this key pest, supporting timely management decisions. Economical and fast methods, such as the bagging or tapping method, can complement general surveys of the thrips complex but do not replace the precision of sticky traps for estimating overall density, especially when the goal is to apply control measures before significant economic damage occurs.

Table 3. Relationship between thrips density estimated by each sampling technique (direct counting, tapping method, bagging method, and blue sticky trap) and absolute thrips density per plant, including slope, R^2, F statistic, and mean insects per 100 plants or per trap.

Technique	Slope ($CI_{95\%}$)	F_{Anova}	R^2	P_{value}	Insects per samples
Direct counting[a]	-	-	-	-	20.54 ± 1.09
Tapping method	0.22 (0.18-0.23)	267.42	0.64	<0.001	1.83 ± 0.32
Bagging method	0.00 (0.00-0.02)	1.17	0.08	0.281	0.28 ± 0.08
Blue sticky trap	0.82 (0.79-0.83)	190.79	0.79	<0.001	2.07 ± 0.83

[a]Absolute density; $CI_{95\%}$= 95% Confidence Interval.

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Authors' Contributions

LBR: Conceptualization; Methodology; Formal Analysis; Investigation; Writing – original draft; Writing – review and editing. SRF: Investigation; Resources; Data Curation; Writing – review and editing. DCN: Methodology; Investigation; Formal Analysis. MFM: Investigation; Data Curation; Writing – review and editing. MMFO: Visualization; Investigation; Writing – review and editing. CGC: Resources; Validation; Supervision. FLF: Conceptualization; Supervision; Project administration; Writing – review and editing.

Conflict of Interest Statement

The authors declare no competing interests.

Ethical Approval

This article does not contain studies involving human participants or vertebrate animals. Insects do not require institutional ethical approval in Brazil.

Data Availability

The data that support the findings of this study are available on request from the corresponding author.

Generative AI Statement

We have used artificial intelligence (AI) tools (ChatGPT, Gemini) just to assist with language revision and text editing.

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