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Postprint: Monitoring Efficacy of a Linear Fence-Trap System for Rodent Populations in Maize Fields

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Date: 2017-11-07T00:00:00+00:00

Abstract

The trap-barrier system (TBS) technology has been applied experimentally and promoted in many provinces and municipalities in China since 2008. Existing research has mostly focused on control efficacy; although several authors have envisioned that this technology could also be used for rodent monitoring, targeted experiments and comprehensive data support remain rare. To investigate the scientific basis for using the linear trap-barrier system (L-TBS) for rodent monitoring in agricultural fields and to explore the correspondence between data obtained by L-TBS and conventional trap-night methods, a comparative experiment of the two methods' monitoring effectiveness was conducted in corn fields in Bole City, Xinjiang from May to October 2015. Through three sets of replicate experiments in the same area, at different locations, and with consistent operational procedures, the agricultural rodent pest species, population dynamics, and reproductive characteristics monitored by L-TBS all matched the results of the trap-night method: chi-square tests for species composition percentages showed house mouse x2=1.50, grey hamster x2=0.54, both less than X20.01; correlation analysis of reproductive characteristics between the two methods showed sex ratio r=0.710 0, pregnancy rate r=0.926 8, testes descent rate r=0.869 2, reproductive index r=0.940 0, all significantly positively correlated. Moreover, L-TBS can capture juveniles and thus more comprehensively reflect population age structure; L-TBS can also capture shrews that are difficult to catch with the trap-night method, making it useful for epidemic prevention monitoring. The capture rates of the dominant species, house mouse, obtained by L-TBS method (X) and trap-night method (Y) were highly significantly positively correlated, with the regression equation y = 0.143 1+0.146 5x (d.f. = 42, r = 0.707 7, P = 0.000 0), demonstrating its association with the trap-night method. The study proves that setting up a 60 m long L-TBS at the edge of a 6.67 hm2 farmland can achieve the goals of rodent pest control and monitoring, offering advantages over conventional trap-night methods in being

more labor-efficient, less labor-intensive, safer, and more operable; furthermore, L-TBS is more convenient for mechanized agricultural operations than rectangular TBS and is suitable for promotion and application in farmland.

Full Text

Monitoring Rodents with Linear Trap-Barrier System in Corn Fields

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Abstract

The trap-barrier system (TBS) has been extensively applied for rodent control in agricultural systems across China since 2008. While previous research has focused primarily on control efficacy, several authors have suggested its potential for rodent monitoring, though targeted experiments and comprehensive data remain scarce. To establish the scientific basis for using linear trap-barrier systems (L-TBS) in farmland rodent surveillance and to explore the correspondence between L-TBS data and conventional night snap-trap (NST) methods, we conducted comparative monitoring trials in corn fields of Bole City, Xinjiang from May to October 2015.

Three replicated experiments were performed in the same region at different locations using identical protocols. L-TBS monitoring of farmland rodent species composition, population dynamics, and reproductive characteristics all aligned with NST results. Chi-square tests for species composition showed no significant differences for *Mus musculus* (^{2} = 1.50) and *Cricetulus migratorius* (^{2} = 0.54). Correlation analyses of reproductive parameters revealed significant positive relationships between methods: sex ratio (r = 0.7100), pregnancy rate (r = 0.9268), testes descent rate (r = 0.8692), and reproductive index (r = 0.9400). L-TBS captured more juveniles, providing a more complete representation of population age structure, and also captured shrews (*Sorex minutus*) that are difficult to trap with NST, enabling epidemiological surveillance.

The capture rates of the dominant species (*M. musculus*) between L-TBS (X) and NST (Y) showed highly significant positive correlation, yielding the regression equation y = 0.1431 + 0.1465x (d.f. = 42, r = 0.7077, P = 0.0000), demonstrating their strong association. This study proves that installing a 60 m L-TBS in 6.67 hm^2 farmland achieves both rodent control and monitoring objectives, offering advantages over conventional NST in labor savings, safety, and operational feasibility. Linear TBS is more compatible with mechanized farming than rectangular TBS, making it suitable for widespread agricultural application.

Keywords: Farmland rodent monitoring; Linear trap-barrier system; Night snap-trap; Rodent population density; Rodent species composition; Age structure; Reproduction characteristic

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Introduction

The trap-barrier system (TBS) is an environmentally friendly rodent control technology that has gained international prominence in recent years. It exploits rodents' behavioral tendency to travel along edges and obstacles, placing traps within barriers to capture them [1,2]. As it uses no rodenticides or chemicals, it is considered a green prevention technology and a valuable measure for ecological agriculture. TBS has been widely applied in rice fields across Southeast Asian countries including Malaysia, Indonesia, and Vietnam. Since 2008, China has conducted application trials in Xinjiang [1,3,4], Anhui [5], Sichuan [6], Jilin [7,8], Liaoning [9], Qinghai [10,11], Guizhou [2,12], and Tianjin [13], with consensus that the technology is particularly effective for dryland crops, offering high capture rates, long-lasting control, safety to humans, livestock, and natural predators, environmental non-pollution, reusable materials, low cost per unit area, and benefits for maintaining ecological balance in agricultural regions. Several authors [2,3,5,9-12] have proposed that TBS could also serve rodent monitoring purposes since it continuously captures intact specimens suitable for dissection and observation.

Historically, farmland rodent monitoring in China has relied primarily on the night snap-trap method (or day snap-trap), which was promulgated as the agricultural industry standard NY/T 1481–2007 "Technical Specification for Monitoring Rodent Pests in Rural Areas" in December 2007 [14]. This standard specifies monitoring content including species composition, rodent density, age structure, and reproductive characteristics (sex ratio, pregnancy rate, average litter size, testes descent rate). Whether TBS can provide accurate information for all these specified monitoring contents and how its results correlate with NST data require further experimental validation with solid scientific evidence.

Previous TBS trials in China have predominantly used enclosed rectangular fences (rectangle trap-barrier system, R-TBS) [15]. However, large-scale mechanized operations are now common in Xinjiang' s rural areas, and enclosed fences placed within fields impede mechanized farming activities. Therefore, this trial adopted the linear TBS technology (L-TBS, or open fence) [15] based on practical needs, using conventional NST as a control to evaluate and compare monitoring efficacy and correlations, aiming to provide an effective technology suitable for modern mechanized agricultural production.

1. Materials and Methods

1.1 Study Site The experiment was conducted in Xiaoyingpan Town, Bole City, Xinjiang Uygur Autonomous Region in 2015. The experimental area featured flat terrain with contiguous corn (*Zea mays*) fields exceeding 33.3 hm^2 per site. The corn variety was 'kws2564' , sown between April 15-20 using plastic film cultivation technology with basin irrigation (6-7 waterings during the growth period). Mechanized field operations including inter-tillage and pesticide application occurred from mid-May to mid-June. Surrounding areas within 1 km included minor plantings of wheat (*Triticum aestivum*), potato (*Solanum tuberosum*), and vegetables.

1.2 Experimental Design and Methods Two treatments were established: L-TBS and night snap-trap (NST), with NST serving as the control for L-TBS monitoring efficacy.

L-TBS Setup: Three replicates were established, with experimental zones separated by >1,200 m to ensure independence. Fences were installed on April 30, with monitoring commencing synchronously on May 1. Replicate II concluded on August 31 due to personnel shortages, while the other two replicates continued until October 10 with corn harvest and stubble plowing.

NST Setup: Three NST replicates were established adjacent to each L-TBS zone, selecting corn fields with similar environments and equivalent rodent densities. One hundred snap-traps were placed daily in each of the three zones along canal edges or field ridges, with one trap every 5 m. Routes were changed every 5 days. NST operations synchronized with corresponding L-TBS groups.

Basic conditions for the six experimental zones are shown in Table 1 .

1.3 Trap Systems

1.3.1 Linear Trap-Barrier System (L-TBS) Trap Barrel: Semi-cylindrical barrels measured 50-55 cm in height, 25-30 cm top diameter, and 30-35 cm bottom diameter (Fig. 1a [Figure 1: see original paper]), constructed from 0.5 mm aluminum sheet. Four drainage holes (<0.5 cm diameter) were drilled in the bottom. Each L-TBS required 12 barrels.

Fence and Support Poles: The fence used metal mesh with $ $0.5 cm aperture and >50 cm height. Support poles were 100 cm steel bars for fence fixation (Fig. 1b [Figure 1: see original paper]). Each L-TBS required 60 m of mesh and 16 support poles.

Installation: Each L-TBS measured 60 m in length and was installed at field edges to facilitate mechanized operations (Fig. 1c [Figure 1: see original paper]). The above-ground fence height was 30-40 cm, with approximately 20 cm buried underground. Support poles were spaced 4-5 m apart. Twelve trap barrels were vertically installed along the fence edge at 4-5 m intervals, with the flat side of each barrel flush against the fence and top edge level with ground surface. A 15 cm × 10 cm opening was cut in the mesh at each barrel entrance for rodent access.

1.3.2 Night Snap-Trap Method (NST) Standard 12 cm × 6.5 cm plastic snap-traps were used with peanuts as bait. Trap barrels, fences, support poles, and snap-traps were all provided by Beijing Longhua Xinye Sanitizer Co., Ltd.

1.4 Survey Content and Methods For L-TBS, each trap barrel was inspected daily each morning, recording captured rodent species, sex, body weight, and body length. Female reproductive status (pregnancy, litter size) and male testes descent were examined through dissection. Barrel mud and water were cleared.

For NST, traps were set in late afternoon and collected the following morning. Capture rates were calculated based on effective trap nights. Rodents were dissected and measured using standard rulers and electronic balances (0.01 g precision). Tools included long-handled tongs (for barrel retrieval), specimen bags, medical scalpels, scissors, rubber gloves, and disinfectants.

1.5 Data Analysis This study focused on four main monitoring contents specified in industry standard NY/T 1481—2007: species composition, rodent density, age structure, and reproductive characteristics, comparing efficacy between the two methods.

All data processing employed Microsoft Excel and DPS Data Processing System software [16] for summation, averaging, significance testing, correlation analysis, and graphing.

2. Results and Analysis

During the 163-day trial period in 2015 (123 days for Replicate II), L-TBS captured 297 rodents across three zones, while NST captured 324, yielding comprehensive observational and dissection data. Comparative analysis of key indicators follows.

2.1 Species Composition Throughout the May-October trial period, three rodent species were captured in Xiaoyingpan Town corn fields: house mouse (*Mus musculus*), migratory hamster (*Cricetulus migratorius*), and brown rat (*Rattus norvegicus*). *M. musculus* was the dominant species, comprising 69.86%-100.00% of captures per zone, followed by *R. norvegicus* (up to 30.13% in one zone). Combined species and capture numbers for L-TBS and NST replicates are presented in Table 2 .

Table 2 shows no significant difference in total captures of the three pest species between methods, though efficacy varied by species. L-TBS performed better than NST for *M. musculus*, worse for *R. norvegicus*, and showed no significant difference for *C. migratorius*. *R. norvegicus*, being large, robust, and intelligent, exhibits strong neophobia and jumping ability, often circumventing barrel entrances or escaping after falling in, making capture difficult with L-TBS.

Chi-square tests of species composition proportions (Table 2) revealed no significant differences between methods for *M. musculus* and *C. migratorius*. However, *R. norvegicus* proportions differed extremely significantly ($^{2} = 9.54 >\ ^{2}{}_{0\cdot01} = 9.21$, P = 0.0045), primarily because L-TBS inadequately captures this species, yielding composition proportions that deviate substantially from reality.

R. norvegicus is a newly invasive species in Bortala Prefecture, first detected sporadically at Alashankou in 1992 via railway transport, with initial monitoring records in Bole City suburbs in 2011 and rapid population expansion beginning in 2013. It has become the dominant species in farmsteads but remains rarely captured in farmland. Prior to its invasion, comparative trials of rectangular TBS (R-TBS) versus NST in Wenquan County during 2008-2013 (Table 3) showed close correspondence in species composition percentages across multiple common species, with non-significant chi-square tests, indicating equivalent capture probability for smaller-bodied species and reliable species composition monitoring with TBS.

Both the 2015 trial (Table 2) and 2008-2013 trial (Table 3) captured numerous non-target animals including shrews (*Sorex minutus*), toads (*Bufo* sp.), and lizards (*Lacerta vivipara*). Shrews (order Eulipotyphla, family Soricidae) are insectivorous and difficult to capture with snap-traps, yet they carry multiple zoonotic pathogens and represent important surveillance targets for epidemic prevention departments. TBS' s ability to capture shrews provides functionality beyond snap-trap methods. Toads and lizards falling into barrels generally survive if promptly retrieved, whereas snap-traps often kill small birds. These factors demonstrate TBS' s ecological advantages.

Due to low capture numbers of *C. migratorius* and significantly reduced captures of *R. norvegicus* by L-TBS, subsequent analyses focus on the dominant species *M. musculus*.

2.2 Population Density of Dominant Species Rodent density serves as an indicator of pest population dynamics. Analysis used capture rates of the dominant species *M. musculus*. Since daily captures per replicate were limited, data were combined across replicates for 10-day periods: three replicates for May-August and two replicates for September-October. Calculation formulas were:

10-day snap-trap capture rate = (Total *M. musculus* captured in period) / (Total trap-nights across 3 or 2 replicates) × 100% (1)

10-day barrel capture rate = (Total *M. musculus* captured in period) / (12 barrels × 10 days) × 100%

Population fluctuation curves (Fig. 2 [Figure 2: see original paper]) show similar dynamic trends between methods despite different capture rates. In late May, high *R. norvegicus* activity occupied snap-traps and displaced *M. musculus*, which then moved to field edges and fell more frequently into L-TBS traps, causing artificially elevated L-TBS capture rates and significantly reduced NST rates for that period.

Using full trial period (May-October) data separated by replicate, regression analysis with L-TBS 10-day barrel capture rate as independent variable (X) and NST 10-day snap-trap rate as dependent variable (Y) yielded the equation: y = 0.1431 + 0.1465x, with highly significant positive correlation (n = 44, r = 0.7077, P = 0.0000). As shown in Fig. 3 [Figure 3: see original paper], all points except one fell within the 95% confidence interval, indicating a strong regression relationship. This demonstrates both methods effectively monitor population dynamics of the dominant species, suggesting potential for developing robust regression equations through multi-year data accumulation to convert L-TBS capture rates to equivalent NST rates.

2.3 Age Structure of Dominant Species Based on biological data for *M. musculus* in northern Xinjiang [17] and the authors' accumulated dissection records, age grouping criteria were established (Table 4) to categorize all captured individuals, with results summarized in Fig. 4 [Figure 4: see original paper].

L-TBS captures included five age classes: juvenile, sub-adult, adult I, adult II, and old, with generally younger individuals. NST captures comprised only four age classes (sub-adult, adult I, adult II, old) with older individuals predominating. This occurs because active, heavier rodents more easily find and trigger snap-traps, while juveniles $ $7.5 g have limited mobility and insufficient weight to activate traps. L-TBS barrel openings flush with ground level allow edge-traveling juveniles to fall in easily. Thus, L-TBS provides more complete age class representation for comprehensive monitoring analysis.

2.4 Reproductive Characteristics of Dominant Species The 2015 trial year experienced low *M. musculus* abundance, limiting monthly captures. Reproductive characteristics required sex-specific analysis excluding non-reproductive juveniles, necessitating combined samples across three replicates for overall dynamic analysis.

Sex Ratio: Sex structure varies significantly across developmental stages. Adult sex ratio analysis focused on adult females ($ 12.1*g*)*andmales*(11.1*g*), *calculatingratiosas* / *andplottingn*
seeoriginalpaper]).*BothmethodsshowedpeaksexratiosinOctoberandsimilaroveralltrends*, *withsignificantpo*
0.71 > *r{0}*.{05})*andnon* − *significantchi* − *squaredifference*(χ^{2}$ = 0.27, P = 0.9982 > 0.05).

Pregnancy Rate: Juveniles and sub-adults are essentially non-reproductive. Since L-TBS captured far more individuals in these age classes than NST, analysis used "adult pregnancy rate = pregnant females / total adult females" to exclude age structure bias, examining only females $ $12.1 g. Results (Fig. 5b [Figure 5: see original paper]) showed peak pregnancy rates in May and October, with lowest rates in July for both methods, consistent with long-term monitoring data. Correlation coefficient r = 0.9268 (P = 0.0078) confirms L-TBS effectively monitors female reproductive dynamics.

Testes Descent Rate: Similarly, "adult testes descent rate = males with descended testes / total adult males" was calculated for males $ 11.1*g.Fig.*5*c*[*Figure*5 : *seeoriginalpaper*]*showsbothmethodspeakedat*100*{0}*.{05}$ (P = 0.0245) demonstrates L-TBS capability for monitoring male reproductive dynamics.

Reproductive Index: Average litter size in *M. musculus* shows limited monthly variation. Combining this with pregnancy rate to calculate reproductive index (= average litter size × pregnancy rate = total embryos / total adult females) provides a more comprehensive measure of population fecundity [17]. Fig. 5d [Figure 5: see original paper] shows both methods with peak reproductive index in May, secondary peak in October, and minimum in July. The correlation coefficient $r = 0.9400 > r_{0\cdot 05}$ (P = 0.0052) indicates significant positive correlation.

Comprehensive analysis of these four metrics confirms that L-TBS capture and dissection observations can obtain monitoring results equivalent to NST for rodent reproductive characteristics.

3. Conclusion and Discussion

Since 2008, TBS application trials in China have focused primarily on control efficacy [1-13], with limited targeted experiments and comprehensive data supporting monitoring applications despite scholarly proposals. This trial, using the current standard NST as control, investigated the correspondence between L-TBS and NST data through five months of continuous monitoring in Xinjiang corn fields. Results demonstrate: (1) L-TBS accurately reflects regional farmland rodent population dynamics and clearly monitors damage peaks. Highly significant positive correlation between capture rates enables establishment of robust regression equations, suggesting potential for L-TBS data conversion to equivalent NST density estimates. (2) L-TBS captures diverse rodent species plus shrews important for epidemic prevention that are difficult to trap with NST. Combined with 2008-2013 data, TBS reliably reflects species composition proportions for smaller-bodied rodents equivalent to NST. (3) L-TBS captures complete age classes of dominant species, compensating for NST' s deficiency in juvenile capture. (4) Despite low *M. musculus* abundance in the trial year requiring combined replicate samples, correlation tests showed L-TBS monitoring of reproductive characteristics (adult pregnancy and testes descent rates, average litter size, reproductive index, and sex ratio) matched NST dynamics.

These four aspects provide strong evidence that L-TBS offers monitoring efficacy comparable to NST. Establishing highly correlated regression equations between capture rates addresses for the first time the relationship between these monitoring techniques, providing scientific justification for L-TBS application in farmland rodent surveillance.

The current industry standard NST method is labor- and time-intensive, with equipment loss risks. In sparsely populated Xinjiang with extensive farmland distribution, trap placement routes are long and evening placement/morning collection pose safety risks in remote areas. Alternative methods are urgently needed. This trial comprehensively demonstrates L-TBS' s dual control and monitoring functions, offering labor savings, safety, operational convenience, and long-term reusability. It provides continuous, uninterrupted monitoring data on rodent activity, population fluctuations, and trends across time and space, overcoming NST limitations. Linear L-TBS placement at field edges avoids impeding mechanized operations—unlike rectangular TBS—requiring only 60 m of L-TBS per 6.67 hm^2 plot. However, questions remain regarding optimal L-TBS quantity and placement density for effective control and monitoring, and whether monitoring efficacy varies with field position, requiring further research.

Additionally, this trial revealed that *R. norvegicus*, a recent invader in Bortala Prefecture, is difficult to capture with L-TBS due to its jumping ability and escape behavior, resulting in significantly lower representation in L-TBS samples compared to actual proportions recorded by NST. This represents a critical deficiency for timely eradication of this globally significant invasive pest and urgently requires technical improvement.

Acknowledgments

We sincerely thank Professors Chen Anguo and Zhang Meiwen from the Institute of Subtropical Agriculture, Chinese Academy of Sciences, for their meticulous guidance and assistance in preparing this manuscript.

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