HHS Public Access
Author manuscript
J Public Health Manag Pract. Author manuscript; available in PMC 2025 January 01.

Published in final edited form as:
J Public Health Manag Pract. 2024 ; 30(1): 111–121. doi:10.1097/PHH.0000000000001809.

Operational considerations for using deer-targeted 4-poster tick control devices in a tickborne disease-endemic community

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Abstract

Context: In the northeastern United States, recommendations to prevent diseases spread by blacklegged ticks (*Ixodes scapularis*) and lone star ticks (*Amblyomma americanum*) often rely on individuals to use personal protection or yard-based strategies. 4-Poster Deer Treatment Stations (4-posters) suppress tick populations by treating deer hosts with acaricide, potentially offering a community-wide approach for reducing tickborne diseases in endemic areas. 4-Poster deployment logistics in mainland community settings are not well documented but are needed for future public health tick control efforts.

Program: As part of a public health research effort to design a population-based 4-poster effectiveness study aimed at reducing tickborne disease incidence, TickNET researchers partnered with the Town of Ridgefield (Connecticut) to understand the feasibility and operational logistics of

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All authors included in this manuscript contributed substantively to the work throughout the entire project, including initial project ideas, guidance on project development, logistical research, site selection, project development, analysis, and writing.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

Financial Disclosure: None

Human Participant Compliance Statement: This project did not involve human subjects and therefore did not necessitate Institutional Review Board approval.

deploying 4-posters on public land within a residential community to inform future public health interventions by municipalities or vector control agencies.

Implementation: We deployed three 4-posters on a municipal property from July to December 2020 and used motion-activated cameras to record wildlife activity nearby. We documented per-device operational details, costs, materials consumed, and animal activity.

Evaluation: 4-Poster operation was feasible, and device challenges were easily remedied. Deer visitation and heavy non-target animal use were documented at all devices. Unexpectedly, monthly corn consumption was not correlated with monthly deer-view days. The monthly cost per device was USD$1279 or USD$305 per hectare with an average 21 minutes of weekly service time.

Discussion: 4-Poster use by communities, public health agencies, or vector control programs may be a practicable addition to tick management programs in tickborne disease-endemic areas in the Northeast. Such programs should carefully consider local and state regulations, follow manufacturer and pesticide label guidelines, and include wildlife monitoring. High labor costs incurred in this project could be mitigated by training vector control agency or municipality staff to service 4-posters.

Keywords

4-poster device; white-tailed deer; Lyme disease; tick control; *Ixodes scapularis* ; *Amblyomma americanum*

Introduction

Continuing challenge of tickborne diseases in the northeastern United States

Tick exposure risk poses a public health challenge across suburban landscapes in the northeastern United States, where blacklegged ticks (*Ixodes scapularis*) transmit the causative agents of Lyme disease and multiple other human illnesses.[1,2] In this region, *I. scapularis* are commonly found peridomestically and in surrounding neighborhoods.[3] Further exacerbating the threat for tickborne diseases (TBDs) in the Northeast is the geographic range expansion by the lone star tick (*Amblyomma americanum*), an aggressive human biter that can transmit *Ehrlichia* and other pathogens, and can similarly occupy suburban habitats.[4,5]

Available public health tools to combat TBDs rely on public education and on the vigilance of individuals to engage in regular personal protective behaviors such as performing tick checks or bathing after outdoor activity.[6,7] Alternatively, residential tick suppression measures, including landscape modifications and chemical control, require the willingness of homeowners to employ these measures on their own properties. Although both *I. scapularis* and *A. americanum* abundances in peridomestic settings can be reduced using pyrethroid acaricides,[8–10] no published study has linked this suppression to the reduction of TBD incidence, possibly in part because treating tick habitat only on a patchwork of properties may not reduce tick densities community-wide[11–13] or on a scale large enough to impact TBD incidence.[14] Furthermore, a lack of best practices for decision-making surrounding acaricide use (e.g., product type, timing and location of application) may lead to variability in tick management practices on individual properties, with poorly deployed or ineffective products used.

In individual backyards, tick densities are highly variable and are not directly related to Lyme disease incidence.[15,16] At broader scales, however, tick abundance has been shown to be predictive of disease incidence,[4,17,18] suggesting that public health-led initiatives to reduce tick populations within a community may provide a more effective strategy for managing risk in endemic areas. Regional vector control programs have long addressed the threat of mosquito-borne diseases in the Northeast by monitoring and managing mosquito vectors in risky areas.[19–21] Similar community-wide tick management efforts are not commonly implemented, but have been suggested as an essential step to combatting the threat of tickborne illnesses.[22–24] Tools for region-wide tick management by vector control agencies, municipalities, and other health agencies are therefore greatly needed.

Deer-targeted tick treatment can supplement current prevention measures

White-tailed deer (*Odocoileus virginianus*) play a critical role in the enzootic cycle of TBDs because they are critical hosts for *I. scapularis*[25] and *A. americanum,*[26] have a large home range, and can be abundant in suburban neighborhoods.[27] Deer-targeted tick control tools, such as the 4-Poster Deer Treatment Stations (4-posters), can suppress tick populations across communities and potentially reduce human-tick encounters and disease. This strategy could augment integrated tick management programs that may promote public health education, tick surveillance, and individual efforts such as personal protection and residential acaricide use.[28]

4-Posters attract deer using corn bait, and acaricide is passively applied to feeding deer via treated rollers.[29–41] When deployed at a minimum density of 1 device per 20–25 hectares (ha), 4-posters have demonstrated up to 91% suppression of *I. scapularis*[29,39] and 85% suppression of *A. americanum*.[39] Previous studies have suggested that 4-posters reduce Lyme disease incidence,[42,43] and *Ehrlichia* spp. prevalence in adult *A. americanum* was significantly reduced after three treatment years.[44] 4-Posters require at least two years of deployment in the Northeast based on the 2–3 year *I. scapularis* and *A. americanum* life cycles.[26,45] Targeting *I. scapularis* females in the spring and fall results in reduced egg-laying and subsequent larval emergence, reducing nymphal populations 2–3 years later.[45] Targeting *A. americanum* nymphs and adults in the spring and summer can impact populations 2 years later. Tickicide (10% permethrin solution) is the only acaricide currently approved by the U.S. Environmental Protection Agency (EPA) for 4-poster use, which can limit device placement due to label restrictions. Previous studies noted challenges to device use, including finding suitable placement locations given regulatory restrictions,[39,40] operational and logistical difficulties, damage by wildlife,[39,46–48] high costs,[46,47,49] concerns about safety to people and animals,[41] and reduced efficacy due to alternate food sources.[41]

A previous effort by Centers for Disease Control and Prevention Tick-Borne Diseases Network (TickNET)[50] research partners to design a population-based study to evaluate 4-poster impacts on TBD incidence identified challenges to high density 4-poster installation specifically on residential properties.[40] Results of a parallel TickNET survey suggested that 4-posters are more acceptable to community residents if placed on public rather than on residential properties (C. C. Nawrocki et al., 2022, CDC DVBD, Fort Collins, CO, unpublished data). Few studies have documented detailed logistics of a 4-poster implementation on public lands in residential areas of the Northeast. To inform public health agencies, vector control programs, or community organizations interested in 4-poster deployment, with TickNET partners, we investigated the feasibility of device use and documented logistics and costs of maintaining 4-posters on a public golf course in a suburban TBD-endemic community.

Methods

Study area: town golf course

In partnership with town officials, we selected a municipal 58 hectare (143 acre) golf course in suburban Ridgefield, Connecticut, for this project. The course primarily abuts 0.4–1.2 hectare residential properties on the south, north, and east, and borders forest on the western perimeter. We chose this property based on size, proximity to residential areas, availability of oak-dominated forest suitable for deer and *I. scapularis* ticks, evidence of frequent deer activity, and overall location allowing for compliance with manufacturer's and the acaricide label specifications. We obtained a scientific collector's permit from the Connecticut Department of Energy and Environmental Protection for experimental 4-poster use, as Connecticut restricts deer baiting because of concerns regarding disease spread among wildlife.[51.]

Procurement, placement, and camera monitoring

In June 2020, we ordered three pre-assembled 4-posters from Dandux Outdoors (C. R. Daniels, Inc., Ellicott City, MD), Tickicide (Y-Tex Corporation, Cody, WY), an applicator gun, applicator rollers, warning placards, and leg stabilization sets. We additionally ordered accessories and upgrades (Figure 1; metal feed gates, metal squirrel plates, and heavy duty post springs) based on recommendations from other researchers (M. Cucura, Entomologist, Suffolk County Vector Control, NY; S. Williams and K. Stafford, Chief Scientists, Connecticut Agricultural Experiment Station, Hamden, CT; A. Li, Research Entomologist, USDA ARS, Beltsville, MD; D. Gilrein, Extension Entomologist, Cornell Cooperative Extension, Suffolk County, NY, personal communication). We selected only manufacturer-certified device modifications[52] and procured twice-cleaned whole corn (Nutrena Country Feeds Whole Corn; nutrenaworld.com) from a local agricultural supply company.

On 10 July 2020, three 4-posters were installed on the southern and western edges of the course. Devices were placed on level, open grass or herbaceous meadow ≤20 m to maple-oak forest and ≤25 m to course greens and where easily accessible on foot or by vehicle. Care was taken to place 4-posters ≥91 m (300 feet) from locations where children may play, and therefore not requiring protective fencing around devices.[53] The distance between devices was 0.66–1.5 km with a theoretical treatment area of 63 hectares or 1 device per 21 hectares (210,000 m^2).[40] Per EPA regulations,[53] a Connecticut-licensed pest control operator (PCO) installed and maintained the 4-posters.

Each device was installed with a leg stabilization set and 1.3 cm plastic feed gates, with horizontal plates set to the smallest opening (Figure 1). Pesticide roller preconditioning was performed according to the manufacturer's instructions. Initially, 22.7 kg of corn was added to each corn hopper, and each device was baited until 20 November 2020.[52]

One Hyperfire 2 motion-activated camera (Reconynx, Holmen, WI) was installed by Western Connecticut State University (WCSU) researchers at locations 2–3 m from each 4-poster to record wildlife use. Cameras were set to medium-high or very high sensitivity, capturing three photos and one 5–10 sec video per recording bout with 5 sec of quiet time between captures, and were operated 24 hours per day.

4-poster maintenance and removal

PCO staff visited the devices weekly, documenting observations and actions taken using an inspection checklist (Appendix I). PCO actions included measuring remaining corn, adding corn, applying Tickicide, and as needed, replacing applicator rollers, repairing damage, and cleaning. Based on data from the previous week, weekly corn consumption per device was determined. Using this measurement, and assuming deer consumed the majority of corn, we estimated deer herd size[52] and thereby a corn weight to add that would be sufficient to attract deer but not excessive. Tickicide was applied weekly using the required applicator at the label-specified rate.[53]

WCSU researchers accompanied two PCOs for three weeks to observe and clarify manufacturer and label instructions. The devices were thereafter serviced by one PCO. WCSU researchers retrieved camera data every 1–2 weeks and catalogued observations by recording daily presence of wildlife and human activity at or near each device.

On 10 December 2020, all equipment was removed from the study sites. The devices were cleaned using a high-pressure washer (Power America model 1440, Power America Cleaning Systems, Littleton, MA) and a brush, soap, and water.

Data analysis

The daily presence of deer and other wildlife was quantified based upon our viewing them in photographs or videos within a 24 hr period. For consistency, we deemed a "month" as 28 days. We calculated total animal-view days per month as = *([number of days an animal species was viewed feeding per month]/[number of operational motion-activated camera days per month]) * (28)*. We examined the relationship between monthly corn consumption and animal-view days at each device using a Spearman's rho correlation. To determine whether monthly corn consumption differed across devices, we conducted a one-way ANOVA with Tukey post-hoc pairwise comparisons for normally distributed data and a Kruskal-Wallis H for non-normally distributed data. SPSS Statistics 26 (IBM Corp., Armonk, NY) was used for all statistical tests.

Results

Installation, maintenance, and removal time

Per device, the average installation time was 40 min, and weekly average PCO maintenance time was 21 min. All equipment was removed from each deployment location in 10 min by two PCO technicians, with post-removal device cleaning by two technicians requiring 1 hr per 4-poster.

Operational challenges, solutions, and observations

Several minor issues were corrected in the first weeks of device use (Table 1). We initially encountered difficulty locating some supplies due to cryptic device packaging and noticed that corn measurement tapes inside device hoppers were not accurate. Throughout the study, we observed minor hopper damage, plastic feed gate destruction, applicator-post displacement (knocked down), and Tickicide applicator challenges. Device damage occurred primarily when hoppers were empty, which assumably led wildlife to try accessing the internal device hopper where scant corn may still have remained. Consequently, in August we increased the corn quantity added to each device, intending to prevent feeding troughs from being emptied before the next service visit. Despite this strategy, the troughs still occasionally ran low, leading to additional device damage. No damage occurred to the corn hoppers where the metal squirrel plates were positioned or to the metal feed gates after installation. Devices remained upright during the study.

The Tickicide applicator was difficult to use when <1 ml of Tickicide per roller was required (the prescribed dose when corn consumption was <2.3 kg/week). Tickicide in such small volumes drawn into the applicator did not reach the rollers, mostly adhering to the applicator tubing and measuring apparatus. As a solution, at least 1.5 ml of Tickicide was applied to each roller during each visit to prevent applicator roller desiccation. We replaced all pesticide rollers 4 and 19 weeks after installation, when deemed excessively dirty or damaged.

Weekly observations commonly included finding corn and dirt in the acaricide roller reservoirs, roller posts bent over, corn pieces in the food troughs and around devices, dirt on the hopper, and holes in the ground around 4-posters. Occasionally, dead arthropods were found on pesticide rollers, and squirrels were often observed feeding. Upon 4-poster removal, the ground where devices had been placed was noticeably bare, with holes from wildlife.

Wildlife monitoring

We recorded 108, 119, and 101 of a possible 152 motion-activated camera days for Devices 1, 2, and 3, respectively, due to camera batteries fully dispensing during high activity periods. Time to initial 4-poster discovery by deer varied by device (Figure 2). Deer visitation was consistent at Device 1 from 1 week into the study through November, 2020, with 10–14 deer-view days per month in August-November, 2020. Deer visited Device 2 fewer than five days combined in September and October, 2020, increasing to 18 deer-view days in November, 2020. Deer rarely visited Device 3, with 3 deer-view days in July, 2020, and 6 in November, 2020. After initial device discovery, squirrels and raccoons visited devices consistently. Mean monthly deer-view days varied among devices.

Chipmunks and birds were also viewed at the 4-posters, and we observed bobcats, coyotes, and opossums. A black bear approached, but did not tamper with, a device. During the first 2 weeks of the study, adults and children showed interest in devices. After viewing children close to Device 2, we placed additional signage on and near the 4-poster and surrounded the device with flagging attached to metal fence posts at a height of 1 m. Despite these measures, we subsequently observed humans approaching, but not tampering with, the device on several occasions.

Consumable materials use and costs

Total corn consumption was similar at all devices (392, 404, and 417 kg per device), and monthly corn consumption was not significantly different between devices (Figure 2). Each 4-poster cost USD$1279 per month (USD$305 per hectare) to operate for the 5-month period (Table 2). Of 1270 kg corn added to all devices, 1213 kg was consumed and cost USD$545. For 5 months, the per device corn cost was USD$182, based on a mean of 423 kg (±58 SD) of corn added per device, and the mean Tickicide cost per device was USD$63 (±6 SD), based on a mean 1051 ml (±105 SD) applied. Corn, Tickicide, and other consumables cost approximately USD$61 per month per device (Table 3).

Discussion

We assessed the feasibility and documented the logistics of operating three 4-posters on a public golf course in a suburban TBD-endemic residential setting to inform public health, vector control, or community tick management programs in the Northeast. Following the manufacturer’s and Tickicide label specifications, we found that device operation was not complicated, and practicable solutions were available for most device challenges encountered.

Corn consumption rate may not accurately estimate deer usage

Although we observed more monthly deer-view days at one device, we found that monthly corn consumption was the same across devices in this study. The discrepancy between corn consumption and deer-view days suggests that non-target animals may have consumed significant corn volumes, given the heavy non-target raccoon and squirrel use observed, though one study reported that 4-poster corn consumption by raccoons was likely not significant.[39] Another explanation is that deer visited 4-posters more frequently each day during high corn consumption periods, which would not be captured in our analysis. Nevertheless, our findings suggest that corn consumption alone may not be a reliable method for estimating deer usage of 4-posters.

Wildlife monitoring to estimate deer usage

We can only speculate, given our data, why corn consumption and wildlife visitation patterns varied by device, as all devices were placed in areas with evidence of deer activity and with similar vegetative structures. The trend of increased wildlife activity and corn consumption at Device 1 in October and at Device 2 in November may have been due to decreased abundance of other food sources, to animals adding fat reserves before winter, and/or to animals becoming accustomed to finding food at the 4-posters. We recommend that 4-poster programs include wildlife monitoring using motion-activated cameras to ascertain deer usage and to relocate devices if deer use is rare.

Non-target wildlife use of 4-posters

Other researchers have documented heavy use of 4-posters by non-target animals.[39,46–49] Studies have suggested benefits of treating ticks on raccoons,[29] but this advantage may be offset by the potential reduction in 4-poster efficacy by raccoons knocking down applicator posts and by potential rabies spread among congregating raccoons.[54] As a black bear approached one device in this study, installing electrified fencing around 4-posters may be considered or even required in regions where bears are present,[55] though it is unclear whether such fences reduce deer access to devices.[46] Programs considering 4-poster implementation should determine whether black bears frequent an area, as placing devices in communities with bear activity may compromise human safety. Furthermore, electrified fencing may be considered a safety concern in public settings.

Per household 4-poster costs

Overall, expenses for the 4-poster and, in our study, labor, were significant. We spent over USD$19,000 to operate three devices. Initially, the cost appears prohibitively high, but may be put into perspective by examining the number of households being impacted. Had we placed 4-posters to maximize the number of residences impacted while satisfying regulatory placement requirements, approximately 21 households could have received tick management benefits from one device. In such a scenario, the 4-poster cost per household would be USD$305 or USD$487 for a 5- or 8-month period, respectively, in the first deployment year, which includes the device and upgrades costs, and USD$250 or USD$404, respectively, over subsequent years. As one residential acaricidal treatment typically costs USD$250–500/ha, per household 4-poster costs compare favorably.[35,36,56–58]

The relatively high labor costs in this study could be mitigated by municipal vector control programs whose staff may include licensed PCOs who can service the devices. Slightly increasing property taxes is a solution employed by a Mason’s Island, Connecticut, association to cover costs of acaricidal and 4-poster treatment.[59] Labor costs in our study followed a contract fee of USD$200 per servicing visit; paying an hourly rate could be more cost-effective, considering the low average weekly maintenance time (21 min) per device in this study. The per visit PCO charge in this study, however, is on par with commercial PCO tick management fees in the Northeast. In a 2017 survey of PCOs in Pennsylvania, New Jersey, and New York, 61.4% of respondents charged >USD$151 per visit to treat a 0.4 ha residential property with conventional acaricide. As southwestern Connecticut has relatively high costs, corn and labor prices may be higher than in other regions. This should be considered when examining the overall costs of deploying 4-posters.

Efficacy of upgrades and accessories

The 4-poster upgrades and accessories purchased showed varying levels of effectiveness. While the upgraded applicator springs did not break, as occurred in other studies using standard post springs,[39] they did not always return to their upright positions after displacement. Unless the standard post spring is improved, we recommend future projects purchase the heavy-duty post springs and staff visit devices 1–2 times per week to raise fallen posts. We also recommend purchasing the leg stabilization set to prevent device tip-over, as well as metal squirrel plates and feed gates, which should be installed before device deployment. Other researchers reported similar issues with applying Tickicide and, with more extensive use, dosage markings wore off, and applicators failed.[39] Unless a new Tickicide applicator is designed, future projects may encounter similar applicator difficulties. With heavy device use, studies have reported that the rollers can become dry between weekly services, and therefore devices were serviced twice a week during high corn consumption periods,[39] another consideration for future projects.

Uncomplicated device maintenance and access

Device maintenance was uncomplicated due, in part, to selecting locations that were easily accessed by vehicle. Accessibility can have tradeoffs, however, as convenient device locations may have allowed golf course patrons to see devices despite efforts to place them away from view. Installing fencing around devices may be needed if placed on properties frequented by the public. Other components of project success included the PCO having space large enough for device storage and a refrigerated cooler capable of storing large quantities of corn bait, protecting it from pests.

Important regulatory considerations

Before deploying 4-posters, communities must consult with regulatory agencies regarding guidelines for use. For example, the presence of bears[55] or restrictions to wildlife baiting due to potential disease spread among congregating animals[46,60,61] may impact permissions. However, direct contact among deer was shown to be comparatively low when using 4-posters,[39] and no evidence of chronic wasting disease was found among deer tested in a Virginia 4-poster study.[46] Furthermore, communities in Connecticut, Maryland, and Long island, NY, have successfully executed 4-poster projects despite wildlife feeding restrictions.[32,39,59] In addition, in some states only licensed PCOs may apply Tickicide, which may impact the cost and labor associated with 4-poster initiatives.

Three year installation requirement

When used for tick management, 4-posters need to be installed for at least 3 years and from April to November to have the greatest impact on *I. scapularis* and *A. americanum* populations, due to the life cycles and activity periods of these ticks in the Northeast. Given the 5-month duration of our study, we could not assess challenges associated with multi-year use in more variable environmental conditions. In addition, while we examined animal-view days over the project period, we were unable to measure the feeding time or corn consumption rate of each animal at each device, which would produce more precise results of corn consumption by each animal type.

Implications for policy and practice

4-Posters, deployed on public lands in residential settings, can be a feasible component of an integrated TBD prevention effort implemented by public health departments, vector control agencies, or community organizations. Such an integrated program can include currently deployed tools such as public health education, individual-based personal protection and residential acaricide treatment, as well as community-wide tick population monitoring and control, by employing landscape-wide tick suppression measures such as 4-posters and/or community property acaricidal treatment. Based on our study findings, we suggest the following priority considerations for future 4-poster use:

- Determine local and state permitting requirements, especially regarding wildlife congregation related to potential disease spread;
- Reduce device damage by ordering specified accessories and upgrades and following manufacturer's guidelines;
- Place devices at easily accessible sites and have secured storage for corn to prevent pest damage;
- Monitor device usage with motion-activated cameras, as corn consumption may not accurately reflect deer usage;
- Hire an experienced PCO (if required by your state) and allow time for proper PCO training;
- Use fencing in areas frequented by the public.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

This work was supported by the Centers for Disease Control and Prevention, Emerging Infections Program via Cooperative Agreement U50CK000488. L. Eisen, B. Schappach, R. Krell, E. Baxley, and D. Weiss provided invaluable assistance on this project. We thank K. Stafford, S. Williams, A. Li, D. Gilrein, and M. Cucura for insight on 4-poster operation and accessories.

The findings and conclusions of this study are by the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention, Yale University, or Western Connecticut State University. The mention of commercial products does not represent an endorsement by the authors, the Centers for Disease Control and Prevention, Yale University, or Western Connecticut State University.

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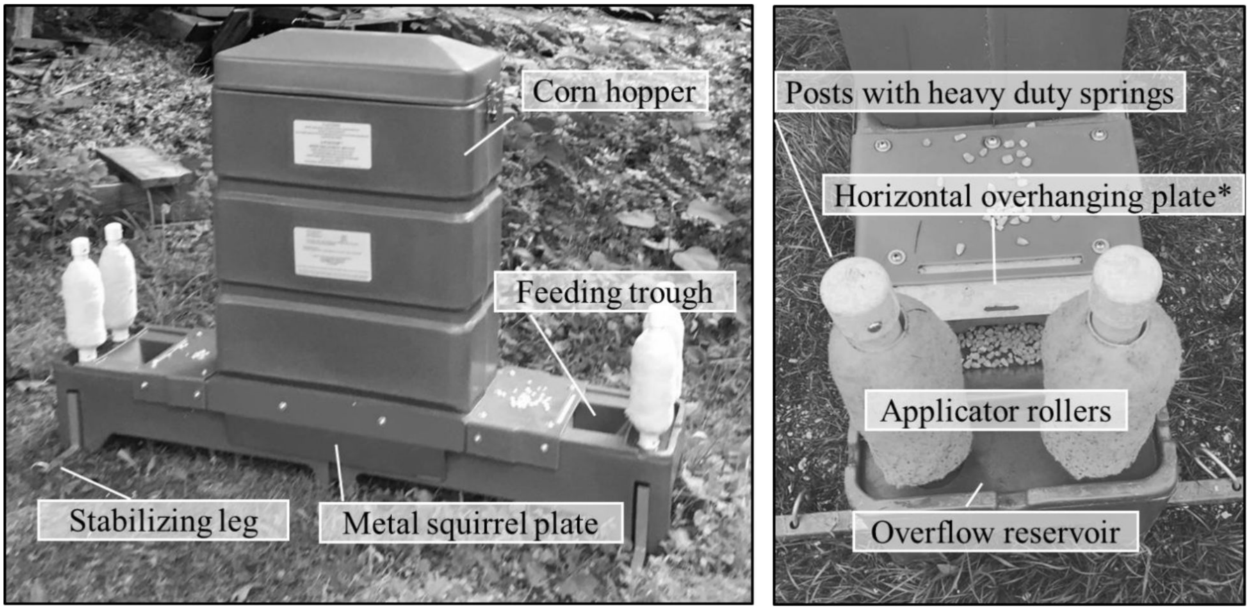

Figure 1. C.R. Daniels 4-poster device.

*Also referred to as slide adjuster plate.

Front and side views of 4-poster device used in this study. Upgrades and additional accessories included (i) the metal squirrel plate set (metal "shields" attached by the manufacturer onto both sides of the lower portion of the plastic corn hopper to minimize damage by wildlife); (ii) heavy duty applicator post springs, installed inside applicator posts (which replaced the basic post springs to better enable posts to return to the upright position after being pushed over by animals); (iii) metal vertical feed plates (to replace plastic ones if damaged); and (iv) the leg stabilization set (to prevent device tip over).

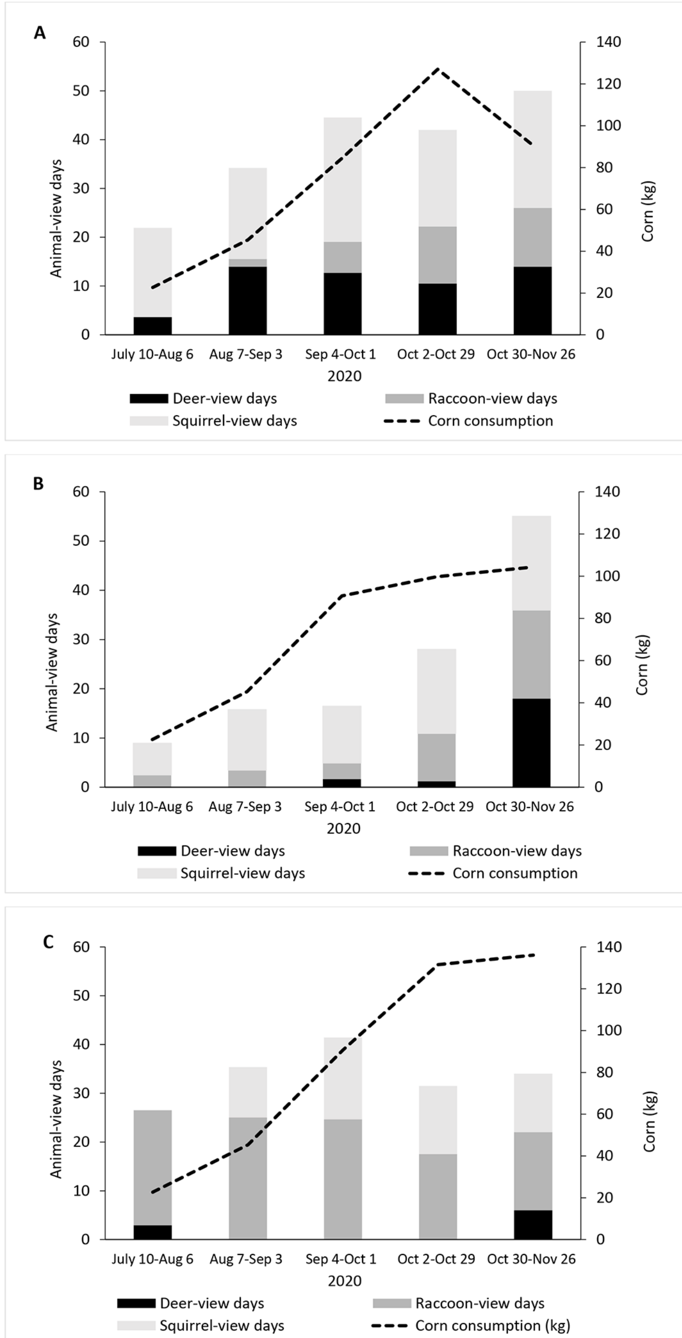

Figure 2. Number of deer-, raccoon-, and squirrel-view days at devices and total corn consumed (kg) per 28 day month.

(A) Device 1, (B) Device 2, (C) Device 3. Monthly (28 day) corn consumption was not significantly different between devices for the study period (ANOVA F=0.130, p=0.880; Device 1, mean=74 kg ± 41 SD; Device 2, mean=75 kg ± 36 SD; Device 3, mean=85 kg ± 51 SD).

Table 1.

Challenges and solutions for 4-poster use in this study

Encounter date	Challenge	Solution	Outcome
Installation	Manufacturer-provided corn measuring tape did not accurately reflect corn weight.	• Determined that 2.5 cm of leveled corn from flat bottom of corn hopper = approximately 4.5 kg. • To measure corn remaining in hopper, corn was leveled (with a 30×5×10 cm piece of wood), corn depth was measured to flat hopper bottom with rigid measuring stick, and corn weight was calculated by conversion measurement above.	Successful
Installation	White plastic horizontal overhanging plates could not be located initially (Figure 1).	• Plates found hidden within unit and held in place with screws. • Adjusted to smallest opening and did not need further adjustment throughout study.	Successful
23 July 2020	One hopper lid latch was found broken.	Latch replaced 1 week later with free manufacturer-supplied replacement.	Successful
6 August 2020 (hoppers empty for ≥7 days)	Wildlife damage to: • plastic portions of corn hoppers, • plastic vertical feed gates.	Corn hopper holes repaired with 2-Part Epoxy (Gorilla Glue Company, Cincinnati, OH).	Successful
Mid-August 2020	• Large holes in plastic feed gates, allowing open access to corn.	Plastic feed gates replaced with metal upgrades with same sized ports (1 cm).	Successful
	• Damage to horizontal plates and plate guards.	Did not repair plates or plate guards.	No impact to performance
Mid-August to 10 December 2020	Damage to plastic parts of corn hopper when empty.	Added 22.7– 45.0 kg of corn weekly/device to prevent hoppers from running empty without leaving overabundance of corn.	Mixed success
Throughout study period	Suboptimal Tickicide applicator functioning, especially with small volumes.	• ≥1.5 ml of Tickicide applied per roller to ensure some acaricide reached rollers to prevent them from drying out.	Mixed success
		• Rollers thereafter checked weekly for dryness. If dry, small volume of Tickicide applied regardless of corn consumption.	Successful
Throughout study period	Upgraded post springs did not always return to upright position.	• At weekly visits, posts manually returned to upright position	Mixed success

Table 2.

4-poster device costs

	Year 1		Years 2+	
Per device (USD$)[1]	**Annual deployment period**			
Item	**5 months (this study)**	**8 months**	**5 months**	**8 months**
Fixed costs (device with accessories and upgrades)[2]	1,090			
Consumables (corn added, Tickicide, rollers, repairs)	307			
Pest control operator (PCO) labor (storage, installation, removal, cleaning)	5,000			
Total cost	**6,397**	**10,235**	**5,307**	**8,491**
Per hectare cost	**305**	**487**	**253**	**404**

[1] At a density of 1 device/21 hectares, not including research staff labor. PCO contract prices per device were USD$300 for storage and installation, USD$200 for weekly service, and USD$300 for removal and cleaning.

[2] Required accessories: Tickicide applicator gun and solution, applicator rollers, and warning signs.

Optional upgrades purchased included the metal squirrel plate set, heavy duty applicator post springs, metal vertical feed plates, and the leg stabilization set.

Table 3.

Average monthly labor (time and cost) and consumable materials cost per 4-poster device[1,2]

	Maintenance		Tickicide		Corn		
Month[3]	**Time (min)**	**Cost (USD$)**	**Applied per device (ml)**	**Cost (USD$)**	**Consumed (kg)**	**Added (kg)**	**Added cost (USD$)**
1	113 [57]	800	190.3 [3.3]	11.3 [0.2]	22.7 [0.0]	22.7 [0.0]	9.8 [0.0]
2	80 [13]	800	211.0 [5.0]	12.5 [0.3]	45.4 [0.0]	52.9[13.1]	22.7 [5.6]
3	85 [7]	800	132.5 [0.5]	7.8 [0.0]	88.7 [3.4]	90.7 [0.0]	38.9 [0.0]
4	89 [8]	800	173.0 [6.5]	10.2 [0.4]	119.4 [17.2]	151.2 [13.1]	64.9 [5.6]
5	62 [7]	800	274.9 [26.9]	16.3 [1.6]	110.4 [23.3]	90.7 [0.0]	38.9 [0.0]

[1]Means from three devices used in this study, for 20 of the 22 study weeks.

[2]Numbers in brackets denote ±SD.

[3]Month numbers (2020) correspond to the following dates: 1, July 10-Aug 6; 2, Aug 7-Sep 3; 3, Sep 4-Oct 1; 4, Oct 2-Oct 29; 5, Oct 30-Nov 26.

Tickicide cost is based on the price of USD$0.06/ml. Corn cost is based on an average corn price during the study of USD$9.74 per 22.7 bag.