Extension Note
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Seed rain traps for forest lands: Considerations for trap construction and study design

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Abstract

Seed rain studies provide valuable information for forest researchers monitoring exotic species invasions. Plant species move through forests primarily as seeds, and this dispersal is critical to future forest composition. In this extension note, seed trap types are briefly outlined and suggestions made for trap selection. Funnel seed traps are recommended for most seed rain studies, and instructions for building a simple and inexpensive funnel seed trap are given. Study design considerations, such as sample adequacy, trap placement, and blocking of stands, are discussed. In addition, practical methods for sorting and identifying collected seeds are described. Seed traps can provide information about seed dispersal in disturbed forests, and give early warning to forest workers concerned with exotic species invasions.

KEYWORDS: *exotic plant species invasion, seed dispersal, seed rain trap, sample design.*

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Introduction

Seed dispersal is an important attribute determining forest community structure. This is especially true where recent fires and logging have removed forest canopy cover (Ferrandis *et al*. 2001). In addition, the effects of climate change on seed dispersal and distribution are poorly understood (Watkinson and Gill 2002). Therefore, to predict how plant species disperse through a forest, it is important to measure seed rain. Although vegetation surveys are critical to understanding disturbance response, an appreciation of seed dispersal dynamics is equally necessary (Bakker *et al*. 1996). Conducting vegetation sampling after fire or tree harvesting (e.g., Halpern *et al*. 1999) tells us about community composition, but not necessarily about exotic plant migration into newly opened sites. Forests function as both seed sources and as filters of seed dispersal. When a forest is disturbed, its ability to filter and modify seed dispersal (i.e., its porosity) changes. As an example, nearness to the forest edge modifies wind speeds, allowing seeds of exotic plants to reach areas where they were previously absent (Cadenasso and Pickett 2001). These changes in porosity are poorly understood.

A brief discussion of some practical applications of seed rain studies will underline the importance of this often overlooked aspect of forest dynamics. Lack of seeds can limit forest recovery after disturbances (Cubina and Aide 2001). Furthermore, management programs to re-establish important species and speed vegetation recovery are often based on inadequate knowledge of species' colonizing abilities. A seed rain study designed to determine the flux of seeds into disturbed sites can provide important information to the forest researcher. For example, species that are adequately represented in seed rain could safely be left out when developing the revegetation seed mix and important species that are under-represented in the seed rain could be included. If no seed source is available, transplants may be an option. Information from such studies can remove some of the guesswork from re-establishing a functioning forest.

We also know that weed invasion of forests is mediated by weed seed occurrence and travel distance, as well as the relationship of different forest edges to dispersal probabilities. Seed rain studies can address all of these situations. For example, a study of seed rain adjacent to a forest may reveal that weed seed dispersal is considerably less likely where the area is bordered by dense shrubs. Weed control efforts could then be focused primarily in areas lacking this edge filter.

Seed rain trapping studies will be invaluable as we begin to deal with large-scale weed invasions that may result from logging, increased fire frequency or severity, and predicted climate changes.

Seed dispersal through seed rain is thus of critical importance and deserves study. Seed rain trapping studies will be invaluable as we begin to deal with large-scale weed invasions that may result from logging, increased fire frequency or severity, and predicted climate changes. In this paper, I discuss the most common seed trap types and their placement in the field.

Trap Types

Several seed rain trapping methods are available to forest researchers. Two general methods are:

1. trapping on a sticky surface, and
2. trapping in gravity traps.

Sticky Traps

Sticky traps are made of commercially available products (e.g., Yellow Sticky Cards or Tangle-Trap™) that are commonly used in greenhouses to control insect pests. Because seeds on sticky traps are exposed, the trapped seeds remain vulnerable to removal by wind and precipitation. An advantage of this method, however, is the ability to focus trapping on seeds capable of distant travel (Kollmann and Goetze 1998). Sticky cards can be placed at specified heights and orientations above the soil surface. As card height increases, collection of seeds from distant sources is favoured over those from nearby sources. This occurs because most seeds that cross long distances via wind generally tend to travel at greater heights above the soil than heavier, less mobile seeds. Downward seed movement (primarily heavy seeds) is sampled with horizontally placed cards, and lateral movement is sampled with vertically placed cards. Collections using sticky traps may be problematic because insects, dust, and litter can accumulate on the card along with the seeds. Nevertheless, sticky cards are easily placed in the field, making this trapping method a good way to augment a seed rain study. However, it is usually not very successful as a primary seed collection method.

Gravity Traps

Gravity traps include pit traps, surface-placed trays, and funnel traps. I will discuss pit and tray traps briefly and then describe the funnel method in some detail.

Pit and Tray Traps

Pit traps consist of open-top containers buried in the soil. Container size is limited by the practicality of sorting through the volume of material that can fall into the trap. Therefore, pit traps are poorly suited to seed trapping during winter owing to the large volume of litter that may accumulate. Pit traps require bottom drainage holes (except in the driest forest environments) to ensure that seed samples do not stay wet (Kollmann and Goetze 1998). These problems can be reduced by frequent sample collection. Pit traps also capture insects along with the seeds, but raising the top of the pit trap 2 cm above the soil surface reduces insect trapping. However, any seed trap that collects both seeds and insects may result in inaccurate seed counts because of seed predation.

Tray traps consist of shallow containers laid on the forest floor. This method is good for collecting large seeds, fruits, and cones. Collection of small seeds from these trays can be difficult, especially when litter fall is abundant. Researchers sometimes allow the seeds of the seed rain to germinate and grow in the tray, while protecting them with wire screening. If the researcher is interested in identifying individual seeds, a large tray size can greatly increase seed sorting times.

Funnel Traps

Funnel traps concentrate seed collections into a small area and, depending on the trap construction and position, the seeds can be relatively free from predation. Given the problems associated with other trap methods, the funnel trap is probably the best for most seed rain studies (Kollmann and Goetze 1998). I have devised a simple, inexpensive funnel seed trap that allows quick sample collection and can be adjusted from ground level to as high as 1.0 m.

A funnel trap (see Figure 1) consists of a high density polyethylene funnel available from many suppliers. Large funnel diameter is best: a 19.37 cm funnel is commonly available and yields a 0.029 m^2 trap area. A porous collection bag can be sewn from 100μ–mesh Nitex® cloth (a plankton net material available from most biological supply companies). The collection bag, which is attached to the funnel spout with a small piece of duct tape, collects the seeds and allows moisture to escape. For this size funnel, a 9 × 3 cm Nitex bag is adequate. Twice as many bags as funnels should be available as this allows quick replacement of filled bags with empty bags on each collection date. Bags are emptied in the lab, washed, and then reused. Depending on conditions, the duct tape can also be reused for two or three collection periods, and is easily replaced in the field. Each funnel is mounted on 5 cm diameter polyvinyl chloride (PVC) pipe by flexible wire. This wire is passed through holes drilled in the pipe and extends up to the funnel top where it passes through holes in the funnel. The wire should be flexible enough to bend by hand, but stiff enough to maintain a right-angle bend when it is passed through the funnel. On collection

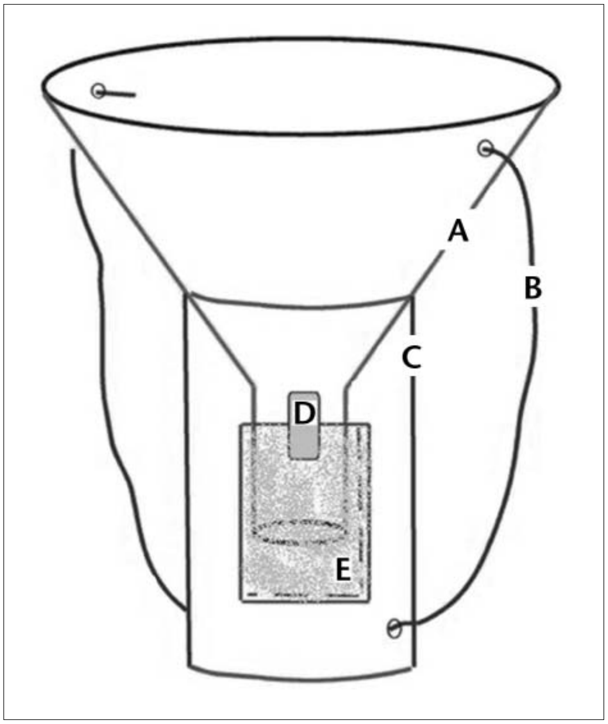

FIGURE 1. Cut-away view of funnel seed trap. High density polyethylene funnel (A) is held by wire (B) to PVC pipe (C). Small piece of duct tape (D) attaches 100μ–mesh Nitex cloth (E) to funnel. Funnel height is determined by study design, but should always be at least 2 cm above soil level to limit insect entry. Funnel is supported at desired height by PVC pipe.

dates, the funnel is quickly removed by pulling the wire straight out from the funnel holes, the full Nitex bags are collected and replaced with empty bags, and the funnel reinstalled. The length of PVC piping used is determined by the desired height of sample collection. Funnel traps are easily built in the lab and then carried to distant study sites in backpacks or on horseback.

Seed Trap Placement

If research interest is primarily in seed dispersal from outside the forest stand, funnels should be placed above the ground; 1 m high is adequate in most forested landscapes (Kollmann and Goetze 1998). This height eliminates most local seedfall, except from trees and taller shrubs. Eliminating potential seed sources reduces the amount of lab time required for seed sample processing and decreases the chances that vagile seeds are missed in large sample volumes. However, if research interest primarily involves seed dispersal from inside the forest stand, the funnel should be placed approximately 2 cm above the soil surface. This height catches most seedfall, but limits insect entry into the traps. On steep slopes, funnels should be level with a gap between the uphill funnel edge and the ground surface. This reduces entry of many insects, especially beetles, which frequently tumble down slopes and fall into traps.

Multiple funnel traps are required to sample seed rain in a single forest stand. Kollmann and Goetze (1998) suggest that 8–10, 20-cm funnels are sufficient to detect common species in forests and grasslands, and to calculate reliable means of seeds per trap. For more assurance of sample adequacy, however, a pilot study is necessary to determine the number of traps required for a specified precision and probability. This allows calculation of an estimated sample mean and variance that can then be used to determine the number of traps needed. If the researcher wants to estimate the mean number of weed seeds entering a forest, the required sample size can be estimated with the following formula (Bonham 1989):

$$n = \frac{t^2 s^2}{(k\bar{x})^2},$$

where: n is the estimated number of traps needed for specified probability and precision; t is the t-table value; s^2 is the pilot study sample variance; k is the precision desired (e.g., $k = 0.1$ allows a precision of 10% from the mean); and $\bar{x}$ is the pilot study mean of weed seeds per trap.

This formula illustrates that the number of samples required depends on the variability of the data, as well as the desired probability and precision. See Elzinga *et al.* (1998) for a discussion of sample size considerations. If the calculated sample size estimate is too large to be practical, using fewer traps may still maintain the desired precision and probability by decreasing the sampling frequency. This reduces the sample variance because fewer null set collections are made (Elzinga *et al.* 1998). Decreased sampling frequency, therefore, has the same effect as increasing quadrat size in a vegetation study.

If statistical tests are planned, funnel traps should be placed at randomly selected locations (Zar 1999). Depending on the local vegetation, however, random placements can be difficult to find later. One solution uses systematic placement of traps from a random starting point on one or more transects in a stand (Hayek and Buzas 1997). The distance between adjacent traps should be great enough to ensure sample independence. Although no simple rule exists to determine this, 3 m between traps is probably adequate in forests without tall shrubs. To best capture the variability of seed dispersal in the stand, transects should be distributed throughout the stand. If a forest stand contains an obvious environmental gradient, the researcher should consider "blocking" the sample distribution (Elzinga *et al.* 1998) to allow statistical examination of intra-stand differences. For example, in a stand with a moisture gradient, one might place equal numbers of transects (and traps) in dry and moist blocks of the stand. If blocked areas are not of equal size, trap densities in each block should be weighted so that sampling intensity is equal in each block.

Traps should be emptied on a regular basis. I have found that a single motivated worker can collect samples from 200 or more traps in a single day (distance between sites and local terrain will cause this to vary). In dry, eastern Cascade forests, a sampling frequency of 3–4 weeks is adequate. With this frequency, samples contain a volume of material that can be sorted quickly and accurately, and the number of samples without seeds is very low.

Seed dispersal occurs year-round, and different species dominate the seed rain at different times. Collection of winter seed rain is important, and seed traps should be left out all winter.

The seasonality of seedfall and the wide range of seed production in individual forest stands make it difficult to generalize about expected variances in the seed rain data. For this reason, it is always best to establish the variability in the stands through a preliminary study; on the basis of these data, the required number of traps can be determined.

Processing Seed Trap Collections

In addition to seeds, trap collections can contain forest litter and soils. There are two primary ways to process these collections and determine their seed content:

1. Germinating the collected seeds and identifying the seedlings; and
2. Identifying seed collections directly from traps.

The first method involves transferring collected material to greenhouse flats and attempting to germinate any seeds in the material. This is referred to as a "grow-out," and requires the identification of all seedlings. Grow-out methods are commonly used because they do not require seed identification skills. There are disadvantages to grow-outs, however. For instance, seeds may be dormant or may require some germination cue that is absent during the grow-out period. In addition, some seeds are known to have variations in their ability to germinate related to the length of time they have been in the soil (Cook 1980). Once seedlings have germinated, their identification is often difficult, and many seedlings die or wilt quickly, leaving the researcher with little or no record of the species. In other cases, seedlings may simply never mature enough to allow identification.

The second method uses direct seed identification from trap collections. This requires that each sample is sorted under a dissecting microscope, and all seeds are removed. Although seed identification requires some training, this is greatly simplified when an identified collection of all fruiting plants at the site is made during the seed trapping period. To augment these collections, nearby seed vector sites, such as roads or trails, should also be sampled. If these collections are done carefully, the researcher can develop a voucher library of identified seeds known to occur in or near the study site. Seeds from this library can be photographed and images stored digitally to aid lab workers in identifying seeds from trap collections. The sample processing can also be simplified when the seeds of only a few species are sought (e.g., when monitoring noxious weeds).

Seed identification is further aided by excellent books containing photos of many types of seeds (e.g., Martin and Barkley 1961), as well as by numerous Internet-based seed image libraries. An advantage of seed identification over grow-out methods is that seed trap collections (separate from the seed library) provide a permanent record of species which can then be sent to experts for identification. In addition, seed identification may provide a more accurate count of seed rain than grow-out techniques because dormancy is not a problem.

The volume of samples may vary significantly from one trap (or collection date) to another. Workers who sort seeds from the sample bags can bias results by putting more effort into some samples than others. A simple time limit per sample does not address this problem because in large-volume samples the first minutes of sorting usually reveal only the large seeds. If time expires before looking for smaller seeds, the sample will be biased to large-seeded species. A convenient solution is to employ a "two-minute rule." During sorting of any sample, a stopwatch should be used to mark when two minutes have elapsed. If, during that time, one or more seeds have been found, the stopwatch is restarted and allowed to run another two minutes while searching continues. This procedure is repeated until no seed is found after a final two-minute search. In this way, workers spend reasonable amounts of time on a single sample, and large-volume samples are not over- or under-searched. The two-minute rule is especially important when processing samples from seed collected during winter because winter snows and rains can result in a large volume of litter in each sample. The use of two minutes is based on the average volume of a single 9 × 3 cm Nitex bag and can be modified for different study designs.

It is important to obtain an estimate of how many seeds are missed in the sorting procedure. Very small seeds, for example, are difficult to find, especially in large-volume samples. I have found that seeds with a maximum axis dimension of 0.5 mm or less are almost never found. Perhaps the best method of addressing this situation is to collect the discarded material from every fifth sample bag after seeds have been removed, and attempt a grow-out with this presumably seed-free material. Seed dormancy in the grow-out will likely result in an overestimate of the researcher's ability to find seeds because some seeds remaining in the sample may not germinate. This grow-out method is still the best practical way to measure seed-sorting accuracy.

Conclusions

Seed traps allow researchers to determine the dispersal of weed and other species through forest stands. Disturbances, such as fire, logging, road, and trail construction, can result in forest edges that are more porous to weed invasion because of changes in wind velocity, humidity, and incident sunlight. Monitoring seed dispersal in newly opened forest lands will aid forest researchers in understanding and predicting weed invasion.

Many seed trap designs exist, but funnel traps appear better suited for most seed rain studies. A simply constructed, inexpensive funnel seed trap can be used to monitor weed invasion. The widely perceived difficulty of seed identification can be greatly reduced when researchers develop a seed voucher library for the study site. Workers can learn relatively quickly to distinguish many species and genera. Seed identification is preferred over grow-out methods because it avoids the confounding problems of seed dormancy and difficulties in seedling identification. In addition, grow-outs often do not result in a permanent record of a collection because seedlings can wilt quickly.

Design of a seed rain study should involve a determination of adequate sample size, careful attention to trap placement, and possibly stand blocking. A study before and after an identified forest disturbance can yield invaluable information about the effects of the disturbance on seed dispersal. As forests are increasingly disturbed by recreation activities, logging, and fire, weed invasions will also increase. Seed rain studies provide one critical piece of the puzzle as we begin to understand forest disturbance dynamics.

Seed-rain studies provide one critical piece of the puzzle as we begin to understand forest disturbance dynamics.

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