GENERAL ARTICLES

A plant plotter for use in demography studies

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Summary

The construction and operation of a simple plant plotter is described, and data given on its performance in demographic studies on the herbaceous weed ragwort (*Senecio jacobaea* L.). The plotter is easy and fast to use, and has performed consistently over a number of years in accurately locating individual plants of ragwort and their separate units of growth in permanent quadrats. It has been used on sloping and uneven ground, and in vegetation that includes upright growing species. The plotter is suitable for use in similar studies on a wide range of herbaceous or small woody species, and is considered to be superior to other devices that have been described.

Introduction

Demographic observations on plant populations have become widely adopted by plant ecologists as a means of gaining an understanding of the factors regulating plant populations (Harper 1967, 1977; Harper and White 1971, 1974; White 1985). Such observations involve the identification of individual plants ('genets') or other units of growth capable of an independent existence ('ramets': after Harper 1977). For herbaceous plants, individual plants are normally identified by their positions in a permanently marked area of ground.

Cullen *et al.* (1978) reviewed the various devices that have been used for this purpose, and described an improved plotting device used in their studies (Cullen and Groves 1977).

The instrument described here has been used in demographic studies on ragwort (*Senecio jacobaea* L.). It is simpler in construction than that described by Cullen *et al.* (1978), it can be transported and assembled just as easily, it is easier and faster to use, and it can be used to record plants in larger areas with the same degree of accuracy as the instrument previously described.

Description, operation and performance

Description

The plotter, which is shown in Figure 1, consists of a rigid bar (A) on which are mounted two spring-retractable tapes (B) held in cradles (C) that allow them to swivel horizontally. In operation, the bar is positioned on two steel pegs (D) inserted into pipes (E) set permanently in the ground. The ends of the tapes are secured to the plotting handpiece (F). The length of each tape drawn from its case when the plotting handpiece is positioned vertically over a plant gives the co-ordinates of the plant.

The bar (A) was constructed from 51 × 25 × 2.6 mm R.H.S. cut to 1050 mm long, with caps welded over the ends. Two 11-mm internal diam. sleeves (G) were fitted through the bar 25 mm from each end and welded at 1000 mm centres. The pegs (D) used to support the bar through the sleeves were made from 11-mm diam. stainless steel rod, 250 mm long, with a stainless steel washer welded 100 mm from the base. The bar is held firmly on the pegs by means of the thumb screws (H). The permanent in-ground markers (E) were made from 11-mm internal diam. galvanized iron pipe, 250 mm long.

The tape cradles were made from 3.2-mm mild steel. The base has a 5-mm high lip to hold the base of the tape, which is clamped in position by means of a thumb screw (I) fitted through a bracket on the cradle. The cradles pivot on bolts, 10 mm in diam., fitted through the bar and secured to each cradle by means of a nut (J) welded on the base of the cradle at the rear end to achieve reliable, easy swivelling of the tape assembly. Holes in the bar for the bolts were drilled 50 mm towards the centre from the mounting sleeves, but to the rear

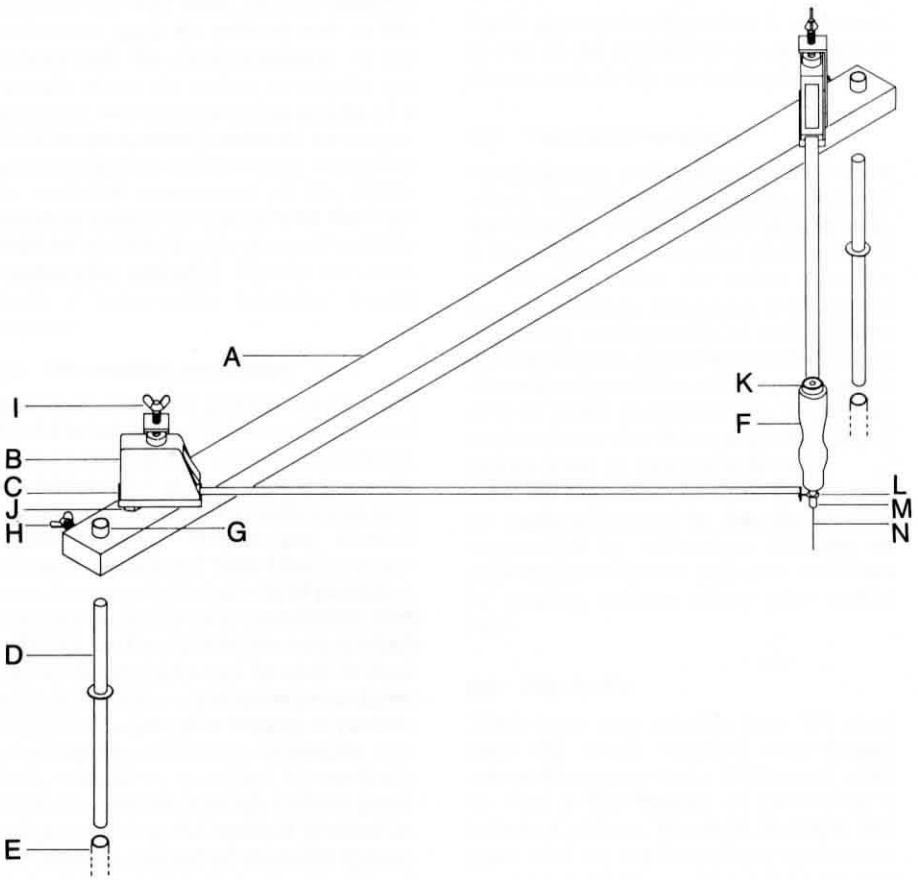

Figure 1 Diagram of the plant plotter showing the rigid bar (A), spring-retractable tapes (B), tape cradles (C), mounting pegs (D), permanent, in-ground markers (E), plotting handpiece (F), sleeves for the mounting pegs (G), mounting-peg thumb screws (H), tape-clamping thumb screws (I), nuts on the cradles securing the pivot bolts (J), 'bull's-eye' spirit level (K), eyelets on the ends of the tapes (L), rubber tubing (M), and the pin inserted in the handpiece (N).

of the bar so that the whole assembly would be better balanced when in operation.

The plotting handpiece (F) was constructed from 30-mm diam. aluminium rod, 100 mm long. The top was faced off in a lathe and a 'bull's-eye' spirit level (K) fitted so that the handpiece could be positioned vertically for recording. The bottom of the handpiece has a turned down shank to accommodate eyelets (L) attached to the free end of each tape. They consist of a 6-mm internal diam. washer welded to a 3.2-mm metal thread, and are attached through a hole in the hook on the end of each tape. The eyelets are held in position on the handpiece with a piece of rubber tubing (M) pushed on to the shank, which facilitates quick and easy removal of the tapes when moving between plots. Recently, a cradle on the bar has been added to hold the handpiece, so obviating the need to remove the tapes from the handpiece during transport. The bottom of the handpiece is fitted with a pointed 1.6-mm diam. stainless steel pin (N). The pin is removable so that pins of different lengths can be used.

After manufacture, all steel and brass components were electrozinc plated to discourage rust and corrosion and thus reduce maintenance.

Operation

The two markers (E) are driven vertically into the ground flush with the soil surface using a guide to hold them in position during driving. The tops are covered when not in use by rubber caps which fit tightly over the markers to prevent filling with soil or other matter. The caps are painted a bright colour so that they are easy to find.

In operation, the pegs (D) are inserted into the markers to the depth of the washers. The bar (A) is slid on to the pegs and held in position by the thumb screws, the height of the bar being determined by the height of the vegetation. The tight fit of the sleeves on the pegs ensures that the bar remains level when raised up on the pegs. In most pasture situations the bar is placed at ground level: it is raised where tall, dense vegetation would interfere with the movement of the tapes. Slight inaccuracies in the vertical positioning of the markers can lead to differences in the co-ordinates between successive occasions when the bar height varies, but this has not proved to be a problem in identifying plants, as all readings are similarly affected, and differences have only been slight.

With the bar in position, the ends of the tapes are brought together and secured to the handpiece. The length of the pin used in the handpiece depends on the height of the vegetation. In our work a 50-mm pin is most commonly used, and it has not been necessary to use a pin longer than 100 mm.

The bar is located on one side of the plants to be recorded. Quadrats of 1 m^2 or smaller, depending on the density of plants, have been used in our studies. The corners of a quadrat can be quickly located by using predetermined co-ordinates read off the tapes. In practice it has been found convenient to leave nails (galvanized, 100 mm) in the ground to permanently mark the corners. These can be easily repositioned if displaced, e.g. by stock hooves. Rulers are placed around the sides of the quadrat to define the boundaries.

In our studies (Friend 1980, 1983) individual ramets of ragwort are recorded by the position of the growing point at ground level. For rosettes, the pin is simply positioned above the growing point. For plants in flower the pin is held vertically against the stem and an allowance made for the radius of the stem before reading the tapes. The spring-retractable action of the tapes, and their free swivelling movement means that the handpiece is the only part of the plotter that has to be manipulated in moving between different ramets. The locking devices on the tapes are used to set the tapes to the co-ordinates for ramets recorded on the previous occasion not observed in a preliminary survey of the quadrat, so that their presence or absence can be more thoroughly checked. Thus, recording is extremely rapid, taking only a few seconds for each ramet.

For graphical presentation of the positions of ramets in a quadrat the distance between the swivel point on the tape cradle and the ramet is computed for each tape. This is done by adding the distance between the swivel point and the point at which the tape is read (65 mm), together with the distance from the end of the tape to the centre of the eyelet (12 mm), to the co-ordinates as read off each tape. Recently, it has been found expedient to shorten the tapes by these amounts (77 mm) so that the co-ordinates may be used directly, without correction, for graphical presentation of these data.

Performance

The plotter has been used for demographic observations on ragwort populations over a period of 6 years on six sites differing in slope, evenness of ground and vegetation cover (Friend 1980, 1983). The maximum slope sampled was 12°. Depressions of up to 1000 mm across and 200 mm deep have been included, as well as sites poached by stock hooves and sites with stones projecting up to 100 mm above the soil surface. Besides herbaceous plants, vegetation cover has included bracken (*Pteridium esculentum* (Forst. f.) Nakai), blackberries (*Rubus fruticosus*, sp. agg.) and seedling trees (*Acacia dealbata* Link, *Eucalyptus* spp.).

Two people are needed to use the plotter efficiently, with one person manipulating the handpiece and observing the plants and the other reading the tapes and recording extra information provided by the observer. This has included for each ramet of ragwort, crown diameter class (three classes distinguished), number of leaves, rosette diameter, damage to the foliage, crown, stem or inflorescence by invertebrates or grazing animals, and seed production.

Up to 175 ramets of ragwort, including seedlings, rosettes and flowering stems, have been recorded from individual quadrats on any one occasion. Seedling densities have often been very high, with densities of 2000 to 5000 m^{-2} being common, and densities up to 15 000 m^{-2} being encountered occasionally. For accurate recording of seedling dynamics, observations are made at 2-weekly intervals during the main germination period, and at monthly intervals for the remainder of the year. Information on growth and development of the seedlings is used to aid in distinguishing new seedlings from seedlings recorded on a previous occasion when the new seedlings emerge in close proximity to the older ones.

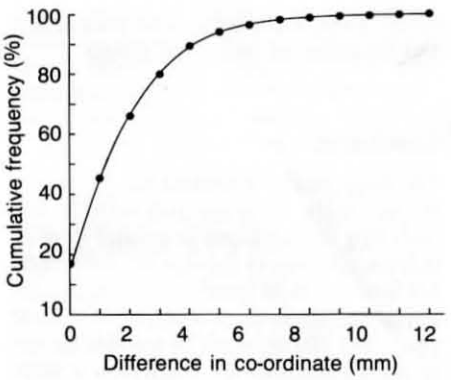

Figure 2 Cumulative percentage frequency of the difference between successive observations in either co-ordinate to the position of a ramet of ragwort as read off the tapes. Data based on 4054 observations taken from several sites on several different occasions. A smooth curve has been fitted by eye through the points.

Second year and older rosettes of ragwort, which have been recorded at 3-monthly intervals, seldom occur closer than 10 mm to one another, making them easier to identify from the previous co-ordinates. New vegetative shoots may arise from these plants, this occurring especially following damage from grazing, stock hooves or invertebrate feeding. Here, records of growth and development may be used to aid in distinguishing between different ramets when they occur in close proximity to one another.

Data on the performance of the plotter in Figure 2 show that differences in the co-ordinates of a ramet from those recorded on the previous occasion rarely exceed 6 or 7 mm. In most of these instances the differences have been due to displacement by hooves or, in the case of seedlings, to the position of the growing point on the ground not being fixed until the secondary root system develops. The speed of recording using the plotter varies according to the vegetation cover and types of plants being sampled. Numbers of ramets of ragwort exceeding 100 h^{-1} have commonly been recorded at the rosette stage of growth in pastures.

The data have been used to show the effects of pasture management, seasonal climatic conditions, and the predators *Homoeosoma farinaria* (Turner) (Ireson and McQuillan 1984) and *Longitarsus jacobaeae* (Waterhouse) (Ireson and Terauds 1982) on such vital aspects of ragwort population biology as germination and seedling survival, growth rate, time

taken to reach flowering, seed production and longevity of individual plants.

Conclusion

The plant plotter described has proved to be extremely accurate and reliable for recording the positions at ground level of individual ramets of ragwort to enable their life histories to be monitored from successive observations over a period of several years. The plotter would be suitable for use in population biology studies on a wide range of herbaceous or small woody plants. There is no minimum area of quadrat on which it could be used and, although 1 m^2 was the largest area sampled, it could readily be used on quadrats up to 4 m^2 (2×2 m). A longer bar would be preferable for larger quadrats.

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