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A Washer for Removing Thickened Roots from Soil[1,2]

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Abstract. A root washer was constructed which rapidly separated Canada thistle [*Cirsium arvense* (L.) Scop. #[4] CIRAR] roots larger than 1.3-mm diam with 96% or greater efficiency from cohesive clay soil. The washer removed 93 ± 15% of 43 200 cm^3 clay soil from Canada thistle roots in 2 h. Small residual soil clods and organic debris were removed by hand after washing. The washing action did not damage the root system. From 4 to 6 h were required to wash the large Canada thistle roots from an equivalent volume of clay soil by hand, without using the washer. Rhizomes, seeds, and tubers also may be separated from soil with the washer. The tank and frame of this washer are durable, and moving parts such as bearings can be replaced easily.

Additional index words. Rhizomes, seeds, tubers, *Cirsium arvense*, CIRAR.

INTRODUCTION

Various washers have been constructed to extract roots from soil. These root washers have used fine meshed sieves and jets of water (6, 16), fine meshed sieves suspended in water (5), angled jets of water spinning on a cone (3), screened cannisters rotating in water (2), cloth bags suspended from laboratory wrist-action shakers (15), and root flotation for separation (9, 11, 14). These washers were designed to extract all roots or root systems from the soil samples. Most designs washed relatively small volumes of soil, were highly labor intensive, and worked best with sandy or loam soil.

Comparing the washing capacity of these root washers is difficult because descriptive information for the various types of washers was inconsistent, vague, or missing. A washer description should contain both the volume of soil which is washed and the volume of the washing container. These volumes may be different depending on the type of soil and the design of the washer. Both the washing time and the time needed for labor also should be specified. Soil type should be included as it may influence the washing time that is required or eliminate the use of certain washers.

Canada thistle is a perennial weed which is propagated by an extensive, spreading root system (8, 13). Maximal rooting depth varies from 180 to 600 cm (10, 12), but 65% of the root dry weight and 50% of the root length are in the top 40 cm of soil (12). Horizontal spread varies from 1.5 to 6.1 m per year (1, 13). Roots larger than 1-mm diam produce shoots from root buds (7), which are the major method of vegetative propagation and spread of Canada thistle. Much time and labor are required to gather and extract the roots from field soil. Thus, an efficient method of harvesting roots could expedite research on Canada thistle.

Our objective was to design and construct an apparatus which could wash roots of Canada thistle that were larger than 1.3-mm diam from large volumes of very cohesive clay soil with minimal manual labor.

MATERIALS AND METHODS

Soil was gathered from field plots with a tractor-mounted, hydraulically powered corer. Individual soil cores were 6.4-cm diam and extended to a depth of 50 cm. Multiple cores as samples from large field plots were combined and washed to extract Canada thistle roots larger than 1.3-mm diam. Random sampling or stratified random sampling is possible with this sampling strategy. The coring tube was fitted with a quick relief bit for use in clay soils, and the bit was lubricated with vegetable oil to facilitate removal of soil cores from the tube. These soil cores were put in plastic bags, marked with metal tags, and placed in a dark room at 0 to 5 C until the soil was washed from the roots.

Washer description. The washing apparatus consisted of a 1.3-m^3 stainless steel tank which was supported by galvanized steel legs and braces (Figure 1). A cradle held nine individual soil cannisters and was supported inside the tank by an offset shaft (Figure 2). The offset shaft was powered by a 186-W motor, activated by a timer, and rotated at 40 rpm. The shaft was offset 6 cm to move the cradle assembly 12 cm vertically and can be separated in the middle by a connecting sleeve (Figure 3) to permit replacement of worn bearings. A 10-cm inlet filled the tank with water in approximately 10 min and a quick-opening gate valve drained the system in approximately 5 min. A pressure arm with rubber pads pivoted at one side of the cradle and provided pressure against the end of the three rows of cannisters to hold the lids on the cannisters and keep the cannisters in the cradle (Figure 3). A butterfly cam-lock latch fastened the pressure arm in place.

The individual soil cannisters consisted of an outer perforated metal support cannister, an inner 14-mesh wire screen with 1.3- by 1.3-mm openings, a rubber gasket, and a lid (Figure 4). The outer support cannister provided strength for the entire assembly. The wire screen retained

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[2] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Dep. Agric. and does not imply its approval to the exclusion of other products that may also be suitable.

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[4] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

roots larger than 1.3-mm diam inside the cannister and allowed the soil and smaller roots to be washed out. The gasket sealed the lid to the upper edge of the inner screen, and the bottom and side of the inner screen were continuous.

Washer operations. Three clay soil cores (4800 cm^3) were placed into each soil cannister (9600 cm^3). Nine soil cannisters were placed on their side in the cradle and locked in place by the pressure arm. The rotating shaft lifted and lowered the cradle and cannisters through the water which created turbulence that washed the soil from within the cannisters. The water was drained from the tank and the cannisters were removed from the cradle. The bottom of the tank sloped towards the water exit to facilitate removal of soil. The washer was placed on a raised, gravel-filled site, and the soil and wash water were drained into a trench adjacent to the washer. The cannisters were removed from the cradle, the washed roots were removed from the cannisters, and residual debris and roots smaller than 1.3-mm diam were removed by hand. Roots larger than 1.3-mm diam were placed between moist towels which were stored in the dark at 0 to 5 C until further processed.

Extraction efficiency. Canada thistle plants were grown in the greenhouse for 2 months until they were 75 ± 19 cm tall and had 36 ± 12 nodes. The root systems were unearthed, washed free of soil and selected portions of roots were segmented into either 5-, 10-, or 20-cm lengths. Each root length had three categories of root diameter for a total of nine categories of roots. The widest portion of each root segment was either 0.9 (0.8 to 1.0)-, 1.3 (1.2 to 1.4)-, or 2.3 (2.0 to 2.6)-mm diam. The root diameter was measured with an eyepiece micrometer accurate to 0.1 mm. Root length and root fresh weight of each root segment were

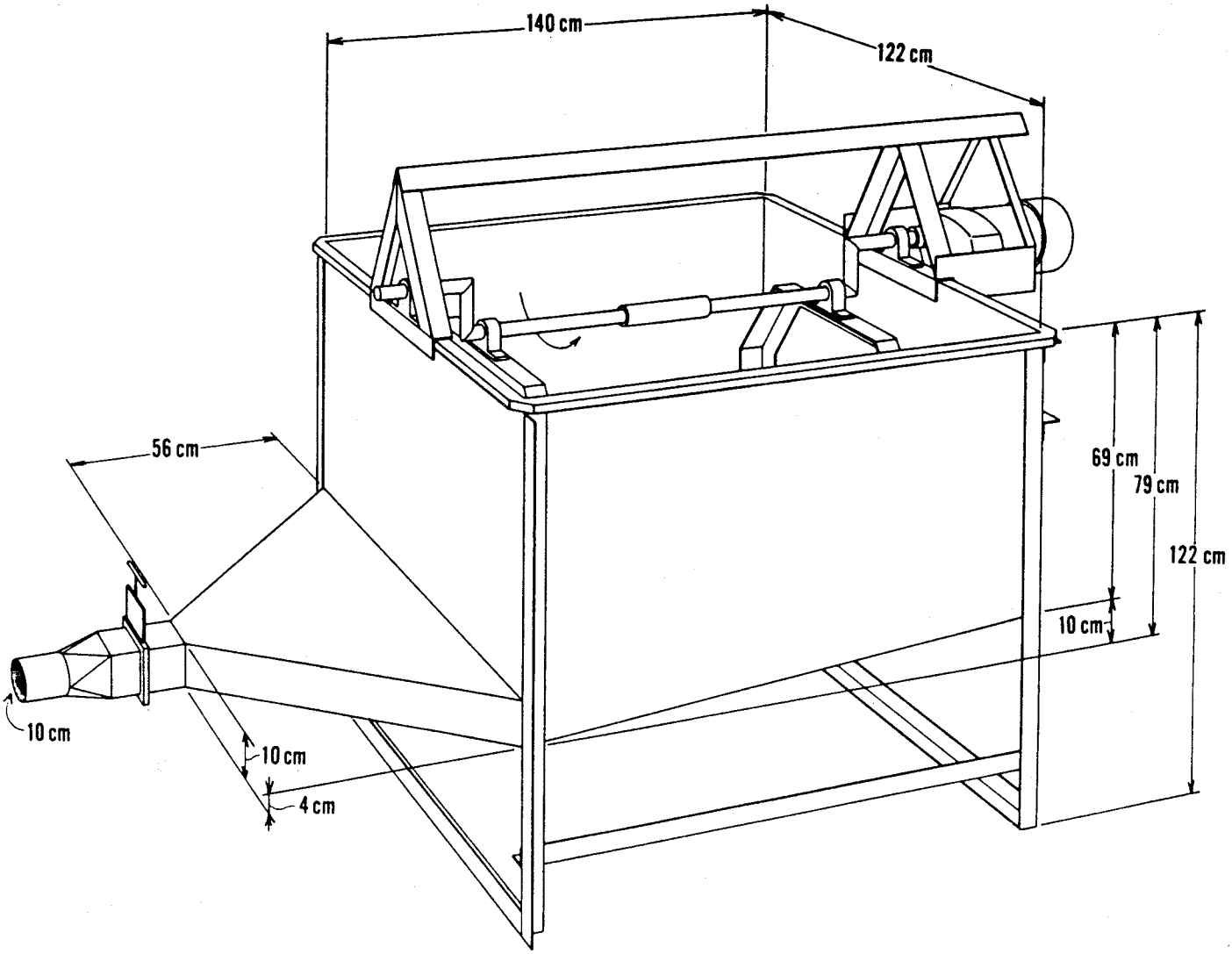

Figure 1. The dimensions of the root washer including the tank with a volume of 1.3 m^3.

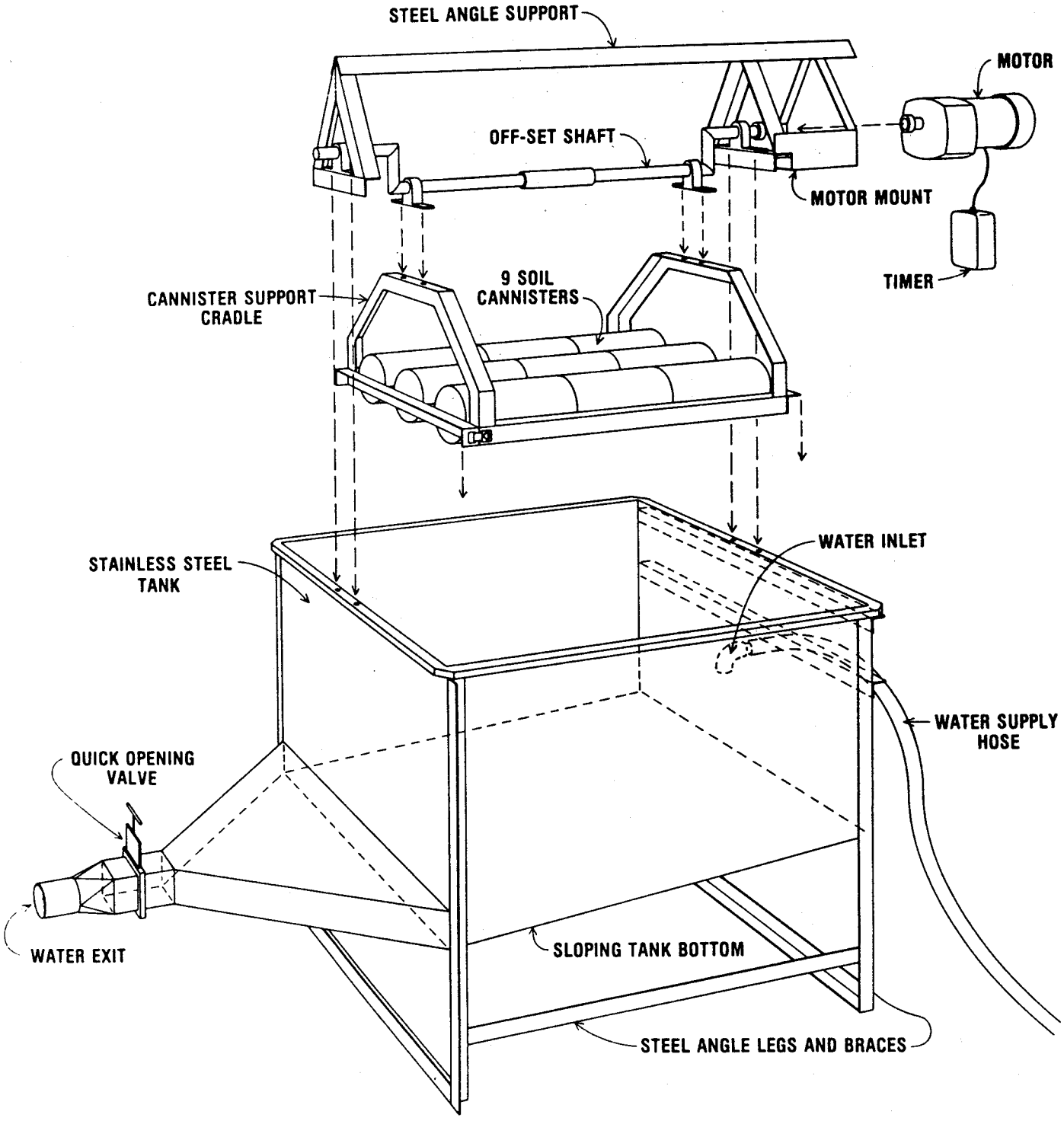

Figure 2. An exploded view of the components of the root washer including the support cradle with nine individual soil cannisters. Features of the washer include an offset shaft which was rotated by an electrical motor, an automatic timer, a water inlet and exit, and a sloped bottom to facilitate soil and water removal.

recorded. Three root segments of each length and one diameter, for a total of nine segments, were placed into each soil cannister and the cannisters were filled with greenhouse potting soil. The soil was washed from within the cannisters with the washer for 3 h. The root segments were separated from the residual debris by hand, and the root length and fresh weight of the nine root segments from each cannister were recorded again. There were three replications and the experiment was repeated once. Data presented are the treatment means and 95% confidence intervals of the combined experiments.

Extraction time. Three clay soil cores (4800 cm^3) containing Canada thistle roots were placed into each of nine cannisters and the soil was processed with the washer. After 1 and 2 h, the percent soil remaining inside each cannister was estimated visually. The experiment was repeated nine times. Data presented are the means and the 95% confidence intervals of the combined experiments.

RESULTS AND DISCUSSION

A total soil core volume of 43 200 cm^3 of clay soil could be separated from Canada thistle roots larger than 1.3-mm diam during one washing with all nine soil cannisters. The very cohesive clay soil could not be broken into small pieces by hand and only filled half of the 86 400 cm^3 volume of all nine soil cannisters. No soil dispersants were added to soften the soil clods because the effect of dispersants on the growth of Canada thistle root buds was unknown. Two h were required to wash 93 ± 15% (mean ± 95% C.I.) of the soil from within the nine cannisters ($P = 0.05$). Unacceptably high quantities of soil remained inside the cannisters after 1 h. However, after 2 h only very hard soil clods which were 2-cm diam or less were left inside the cannisters. The clods were easily removed by hand with the other debris and rarely contained large propagative Canada thistle roots.

Hand labor connected with the root washer included

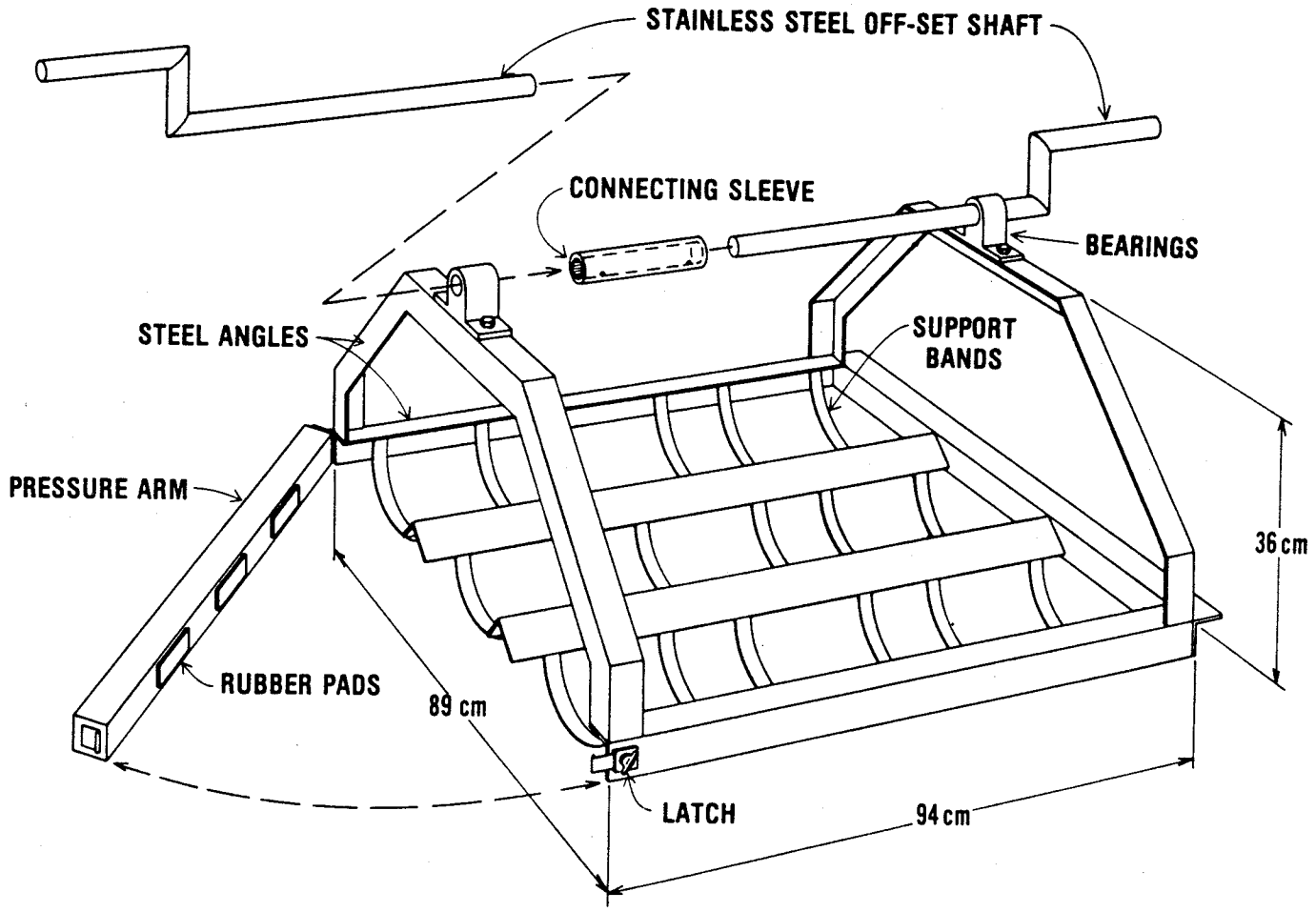

Figure 3. The cannister support cradle and offset shaft. A pressure arm pivoted to force rubber pads against the end of each row of soil cannisters to hold the lids on the cannisters and the cannisters in the cradle. The offset shaft separated in the middle for removal of worn bearings.

transport of the soil samples from the cold room to the washer, loading the cannisters with soil, removing the roots from the cannisters, removing unwanted organic debris, and bagging and tagging the root samples. The time required to wash an equivalent volume of soil by hand, without the washer, was from 4 to 6 h and varied with the person washing the soil and the moisture content of the soil when it was gathered.

Roots with diameters ranging from 0.9 to 2.3 mm remained inside the cannisters for one wash period (Table 1). When root diameters were 0.9, 1.3, and 2.3 mm, the washer was 91, 97, and 100% efficient in retaining roots, respectively. The screen holes of the cannister were 1.3-mm across, yet 0.9-mm-wide roots remained inside. All roots were from 5 to 20 cm in length and apparently the washing action forced the roots to lie longitudinally flat against the screen of the cannister and prevented the roots from being washed out.

The water agitation created by the movement of the cannisters through the water was a gentle washing process and did not damage the Canada thistle roots or root buds. The cannisters remained submerged during the entire wash period, eliminating the violent action of entering and exiting the water. When the samples were washed by hand, roots had to be removed from very hard, cohesive clods of clay soil. Removing the roots from clay soil clods by hand appeared to be more disruptive to the plant material than the washing action of this mechanical washer.

The theory of operation of this root washer is based on a previous washer designed to extract seed from soil (4). However, the previous washer did not have the capacity to wash the large volumes of soil necessary in our experiments on the Canada thistle root system. Other improvements include rapid removal of washed soil from the wash tank, partial disassembly to replace worn parts such as bearings, direct linkage of the motor and offset shaft, a timer to assure consistent washing periods, and the overall increase in strength and durability.

Soil types other than clay may be washed with this washer. Sandy or loamy soils would break apart more easily than clay soil to fill the cannisters with a larger volume of soil (up to 86 400 cm^3 per nine cannisters). Also, sandy or loamy soils would wash out of the cannisters more quickly than clay soil, since only solid clay clods remained in the cannisters after 2 h of washing. Soil with gravel or other abrasive material would damage most types of plant material and therefore could not be washed with this washer.

The type and size of plant material to be washed can be varied. It is possible that rhizomes, seeds, tubers, and other material can be extracted from soil with this washing apparatus. For example, quackgrass [*Agropyron repens* (L.) Beauv.] rhizomes also were removed from soil using this washer (unpublished results). The mesh size of the screen

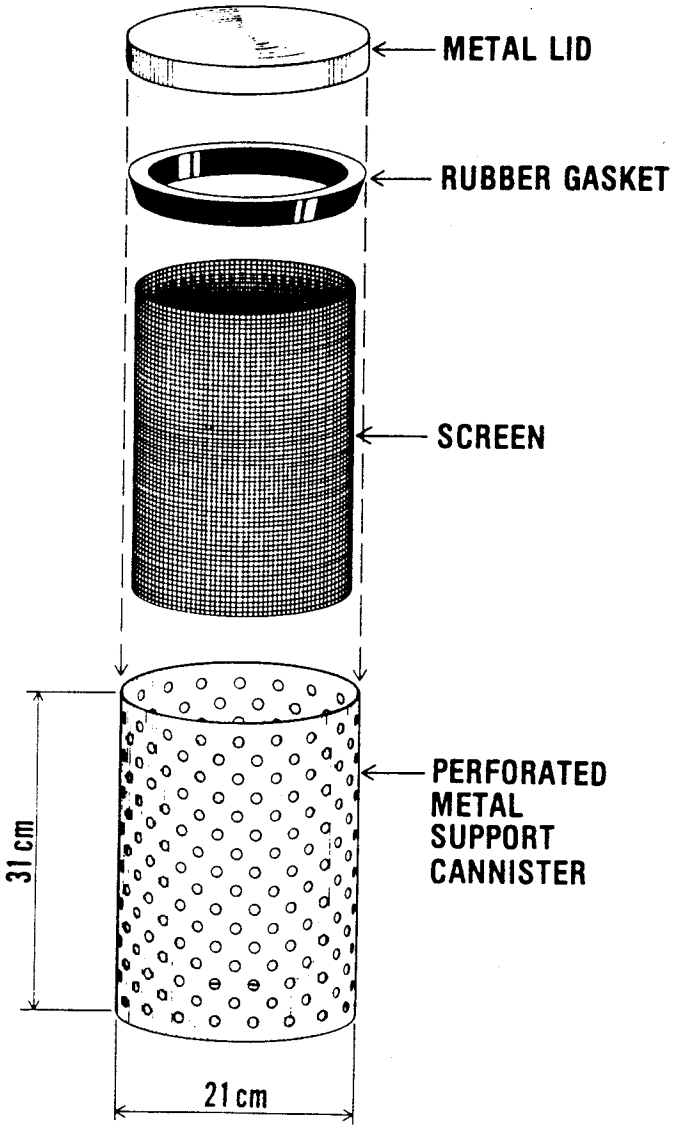

Figure 4. The soil cannister assembly which consisted of a perforated support, a wire screen, a gasket, and a lid. The side and bottom of the screen were continuous.

Table 1. Canada thistle root fresh weight and root length before and after washing roots of 0.9-, 1.3-, or 2.3-mm diam.

Root diameter	Time	Root fresh weight[a]	Root length[a]
(mm)		(mg)	(cm)
0.9	Before washing	513 ± 102	105
	After washing	463 ± 103	95 ± 13
1.3	Before washing	1297 ± 154	105
	After washing	1243 ± 92	102 ± 4
2.3	Before washing	4254 ± 353	105
	After washing	4195 ± 283	105

[a]Means ± 95% C.I.

will determine the size of material which will remain inside the cannister, but may influence the washing time.

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