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Effects of Soil Type and Compaction on the Growth of *Ailanthus altissima* Seedlings[1]

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Abstract

Ailanthus altissima (Tree-of-Heaven) seedlings were grown in compacted and non-compacted mason sand and sandy loam soil. Shoots and roots were measured to characterize seedling development and response to soil compaction. Dry weight increases were shifted to lateral roots when *Ailanthus* tap root growth was curtailed and relative growth rate slowed in response to changes in soil type and compaction. Although total plant dry weights were 50% lower in seedlings grown in compacted soils, increases in dry weights continued to the end of the experimental period.

Index words: lateral roots, growth rate, establishment, Tree-of-Heaven, soil compaction

Introduction

Urban soils are often compacted either by vehicular traffic during excavation and construction work or intentionally to avoid the settling of buildings and roads (1). Frequent foot traffic in areas without paving can also have a similar effect (10). Compaction alters the physical properties of soils by increasing bulk density and by decreasing total porosity and the number of macropores causing plant roots to encounter mechanical impedance and altered water to gas ratios. In fine textured soils, compaction reduces the proportion of those coarser pores which function in the transport and storage of gases. The greater proportion of micropores, which hold available water, is increased so that aeration becomes inadequate. In coarse textured soils aeration may not be reduced, but increased structural strength and mechanical impedance dominates in restricting root growth (11,12). In urban situations soils under pavements have little gaseous exchange with the atmosphere, and oxygen levels can be well below normal (9). Using bulk density as an indicator of compacted soils, soil pits in a Washington, D.C. mall were found to range from 1.7 gm/cc to 2.2 gm/cc (106.1 lb/ft^3-137.3 lb/ft^3) (7). While some trees can initially establish themselves on compacted soils, their roots cannot elongate or penetrate the soil profile sufficiently to support continued growth (2,4,13).

Ailanthus altissima (Miller) Swingle trees often become established in urban sites considered inhospitable to tree growth. Is roots may extend under concrete and asphalt as it grows in pavement seams and cracks of soil. It is also tolerant of a wide range of soil types and is capable of developing into a sizeable tree in the urban setting.

The intent of this project is to characterize the growth of *Ailanthus* (Tree-of-Heaven) in response to soil compaction and to determine which of its responses may be important to its survival in the urban landscape.

Materials and Methods

The two soil materials used in this study were sandy loam topsoil and mason sand. Sand was chosen based on its use, along with gravel, for the construction of sidewalks and roadways (personal communication, New York State Department of Transportation), (8). The planting containers were 20 cm (8 in) diameter polyvinylchloride pipes with a height of 61 cm (24 in). Screening was attached to the bottom of each container to allow for drainage and to retain the soil column. All of the containers were filled to within 2.5 cm (1 in) of the top.

The sandy loam topsoil was sieved through a 0.65 cm (0.26 in) mesh screen, steam sterilized and air dried. For the noncompacted soil treatment, a soil moisture of 10% on a dry weight basis was attained. The containers were filled with 15 cm (6 in) increments of soil and each was stirred to achieve a final bulk density of 1.30 gm/cc (80.75 lb/ft^3). For the compacted treatment, compression of the soil was obtained with a hydraulic press (Baldwin TATE-Emery Load Indicator). With an applied pressire 14 kg/cm^2 (200 lb/in^2) and a soil moisture content of 10%, a bulk density of 1.64 gm/cc was obtained. The soil columns were compacted in four increments of 15 cm each.

The mason sand was air-dried and for the non-compacted treatments, the containers were filled and then watered. After draining and settling, more sand was added until the desired level and a bulk density of 1.67 gm/cc (102.3 lb/ft^3) was obtained. For the compacted sand treatment, a jackhammer with a flat disc was used (8). Four increments of dry sand, 15 cm (6 in) in height, were vibrated for one minute each to achieve a final bulk density of 1.88 gm/cc (117.3 lb/ft^3).

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The containers were placed in greenhouse benches in a randomized complete block design with 4 treatments and 7 replications for each treatment. This design was reproduced 5 times for each of the sampling periods. *Ailanthus* seeds collected in November from a single tree in Ithaca, New York were sown directly, without pretreatment, onto all of the containers. Twenty seedlings were grown in each container and were then progressively thinned to a final number of 4 per pot. Dry weights of the thinned plants were used for the first two sampling data points (Fig. 1). The plants in sand were watered daily because of rapid drainage and those in soil every other day with 200 ppm N-P-K Nutrient solution. High intensity discharge lamps of 400 watts each were used to maintain a 16 hour photoperiod. Air temperature throughout each experimental run was maintained at 21 °C ± 4 ° day and 16 °C ± 4 ° night. At 76 days, the first 28 planted containers were harvested. The soil columns were pushed out intact with a hand hydraulic press and after gently removing the soil and washing the roots, shoot and root lengths and dry weight measurements were made. To be consistent and because only one or two lateral roots formed on those plants grown in the non-compacted soils, the uppermost lateral root was always chosen for determining the lateral root length. This procedure was repeated at 98, 123, 132 and 146 days for groups of 28 containers. For analysis of the relative allocation of growth between shoots and roots of *Ailanthus* seedlings, mean dry weights for sample times after day 76 were calculated and graphed logarithmically. Linear regression-equations were calculated after transformation of dry weights to natural logarithms for each treatment.

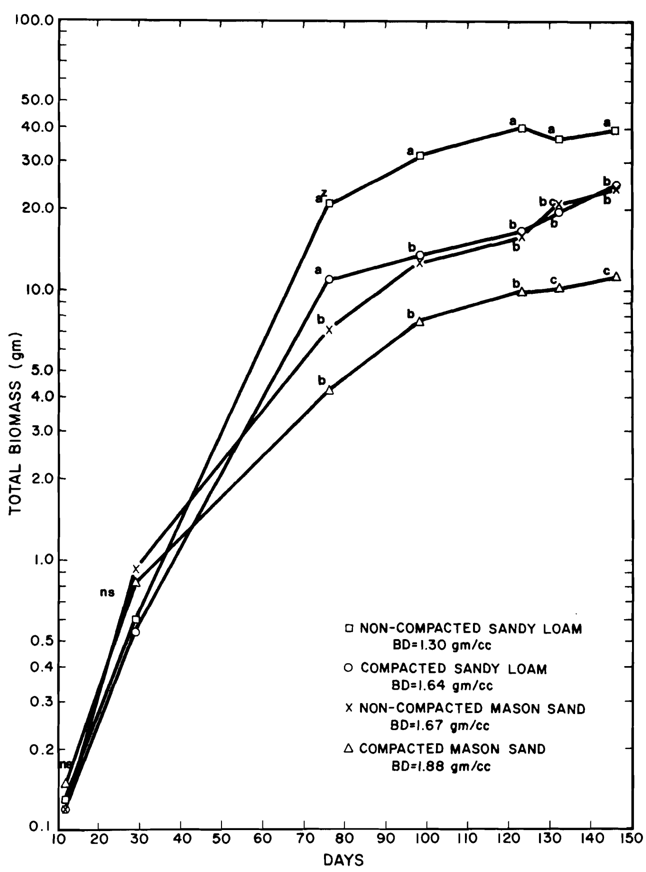

Fig. 1. Effect of compaction in two soil types (sandy loam and mason sand) on the average total biomass of *Ailanthus* seedlings during the 19-week growing period. Each point represents average of 28 plants. Separation of means with Duncan's Multiple Range Test at the .05 level.

Results and Discussion

Total Biomass. Ailanthus seedlings started to grow at essentially the same rate regardless of the soil treatment, but by 29 days growth rate differences were evident (Fig. 1). It was notable that seedling growth was slower in sand than in loam, regardless of compaction. This rate reduction served to moderate the effect of an accidental supplemental light interruption on day 90 which lasted for 4 days. The response of the slower growing seedlings in sand was delayed so that, with light restoration, very little to no defoliation occurred. The faster growing *Ailanthus* in loam lost some leaves causing a drop in total dry weights. Total biomass data showed that *Ailanthus* maintained weight gains in response to soils altered by texture or compaction despite reduced growth rates. Although total plant dry weights were approximately 50% lower in the compressed soils, incremental growth continued throughout the experimental period.

A plot of the natural logarithms of shoot dry weight versus root dry weight showed a linear correlation which was statistically significant (Fig. 2). Slopes of the linear regression curves represent the relative growth rates (RGR) of the two components. If this slope is greater than unity the rate of shoot growth exceeds that of root growth while if it is less than unity, the reverse is true (5). For plants growing in non-compacted and compacted sand the slope values were (0.716 and 0.731) respectively; therefore, the rate of root growth relative to shoot growth was greater with no differences as a result of compaction. In the compacted sandy loam, a greater relative root growth rate also occurred (0.982). *Ailanthus* plants growing in non-compacted sandy loam, however, had a slope value of (1.234) which meant that the rate of shoot growth was greater then to root growth. Although there was a difference in the sandy loam treatments, slopes of the regression lines for all four treatments were not significantly different from each other at the five percent level. The relative shoot-root growth rate was less affected by compaction and change in soil type than the dry weights which were reduced significantly. The data suggested that *Ailanthus* plants maintained a functional balance between above and below ground portions regardless of changes to the soil regime.

Root Growth. The root system showed the most distinctive changes in response to soil treatment differences. *Ailanthus* produced a thick tap root and two to three large, coarse laterals in non-compacted soils. Compaction curtailed tap root growth so that dry weight accumulation was significantly decreased. Lateral roots formed a profuse mass of secondary and tertiary branches which proliferated within the upper quarter of the soil column (Table 1). As a result, lateral root dry weight was not reduced in the compacted treatments (Fig. 3). In addition, increases in lateral root dry

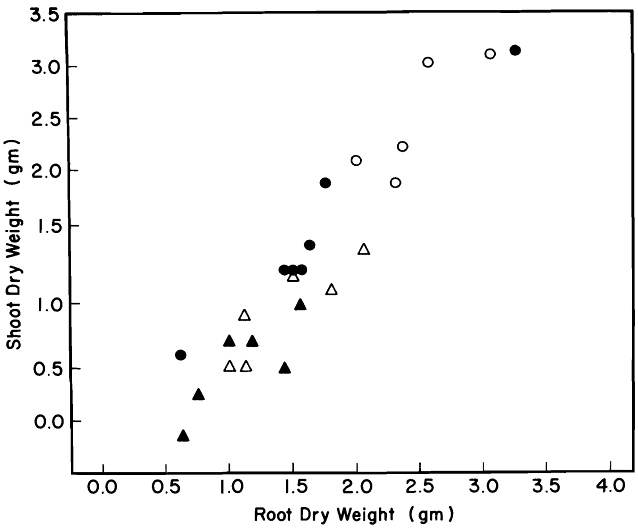

Fig. 2. Relationship of shoot dry weight (gm) to root dry weight (gm) for *Ailanthus* seedlings grown in noncompacted sand (V), compacted sand (V), noncompacted sandy loan (O), compacted sandy loam (O) for 76 days. Each point represents a mean of four plants. (V: y = -0.084 + 0.716X; V: y = 0.437 + 0.731X; 0: y =0.629 + 1.234X; 0: y = 0.055 + 0.982X).

weights partially compensated for the loss in tap root mass and exceeded, at times, the lateral root weights in non-compacted soil. After day 76, lateral roots comprised a larger percentage of the total root weight in the compacted soils. Lateral roots accounted for 50% and 23.7% of the total root dry weight per plant in compacted and non-compacted sand, respectively. The values were 74% and 34% for compacted and non-compacted loam, respectively.

Ailanthus roots demonstrated a morphological plasticity in response to varying soil conditions. In the non-compacted soils tap roots were carrot-like and grew vertically through the soil column. In the compacted loam the tap roots were twisted, gnarled and often split into sections. Tap roots in compacted sand increased in girth and appeared swollen rather than twisted. There were only two to three lateral roots in the non-compacted soils and all were long and flexible circling around between the soil and container wall. In the compacted sand, the lateral roots were spongy and brittle much like those described for roots of cuttings propagated in sand (3). In a separate study, field excavations supported the importance of lateral root growth. In a New York City plot where roots of two-year-old *Acer platanoides* and *Liquidambar stryaciflua* seedlings did not grow beyond the planting hole, *Ailanthus* laterals extended to distances exceeding 1 meter (6). Exploitation of wider and perhaps more advantageous soil environments may explain the success of *Ailanthus* in urban soils.

Significance to the Nursery Industry

Ailanthus responded to soil compaction by altering its lateral root growth from a few long, coarse laterals to a more branched mass of shorter roots. This altered growth habit allowed root growth despite impeded elongation due to soil compaction. The overall growth rate of *Ailanthus* was slowed by compaction as well as by differences in soil type, but the accumulation of dry matter continued in spite of the adverse conditions.

Although *Ailanthus* developed a shortened and branched root system in the experimentally compacted soil, in the natural landscape all of the observed roots were long and scarcely branched (6). These roots may be capable of growing around obstacles and through soil cracks that characterize the subterranean urban environment increasing its chances for finding advantageous soil conditions for continued growth. Nurserymen may be able to select trees with similarly vigorous and adaptable root systems to increase tree success rates within the urban environment.

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Table 1. Influence of soil type and soil compaction on the average lateral root length (cm) of *Ailanthus altissima* seedlings.

Treatment	Soil Bulk density (gm/cc)	Days 76	98	123	132	146
Non-compacted mason sand	1.67	33.40 a[z]	36.41 b	40.46 a	40.86 a	41.56 a
Compacted mason sand	1.88	19.52 a	23.76 c	23.35 b	23.61 b	23.65 c
Non-compacted sandy loam	1.30	28.61 a	46.90 a	42.31 a	38.45 a	48.82 a
Compacted sandy loam	1.64	25.01 a	27.66 bc	26.68 b	24.98 b	32.26 b

[z]Separation of column means with Duncan's Multiple Range Test at the .05 level.

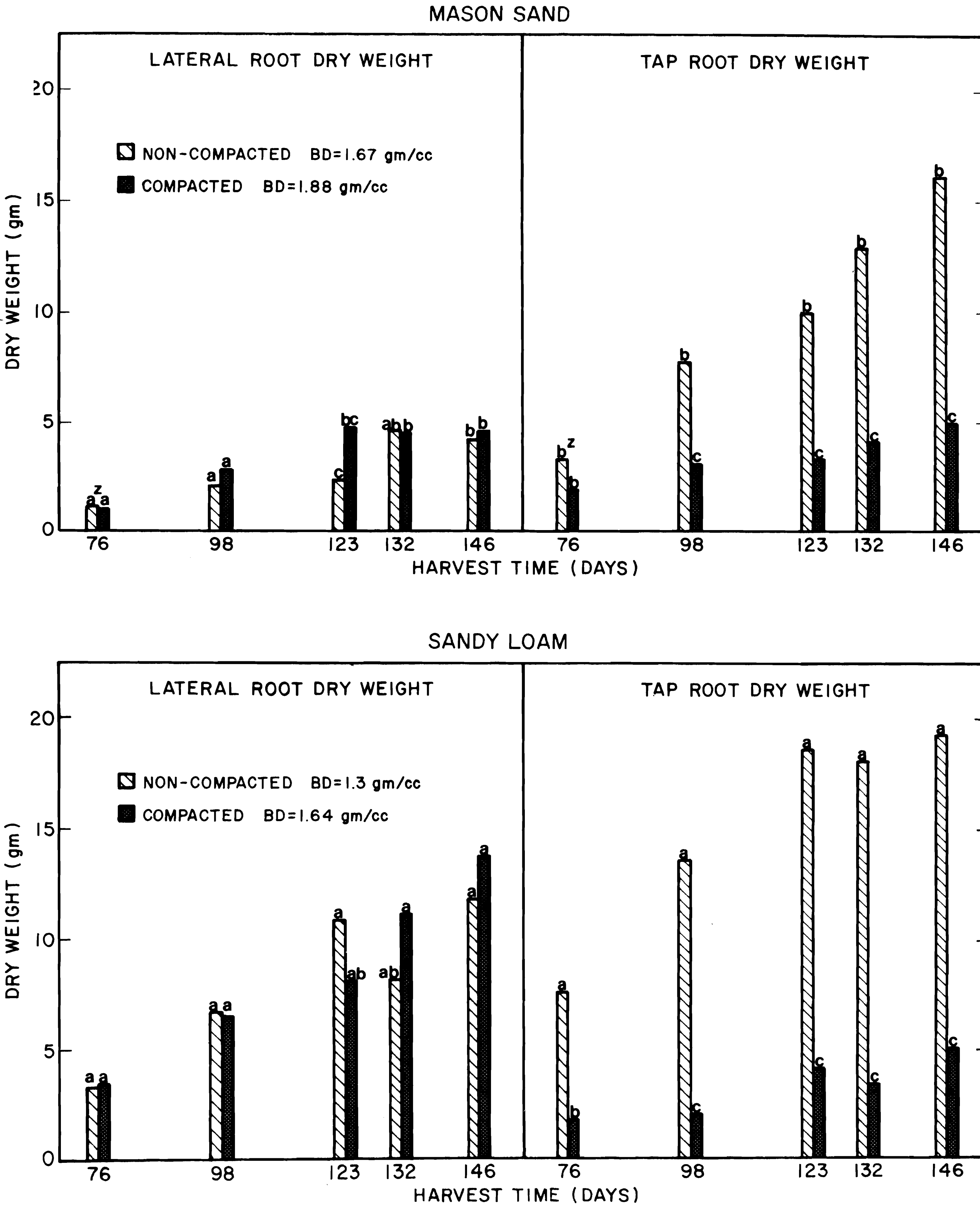

Fig. 3. Effects of soil compaction on the average lateral root weight and the average tap root weight in mason sand from 76 days to 146 days. Separation of means with Duncan't Multiple Range Test at the .05 level.

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Rooting of *Pachysandra terminalis* and *Euonymus kiautschovica* Stem Cuttings Under Intermittent Mist and Outdoor Thermo-blanket Tents[1]

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Abstract

Thermo-blanket tent, intermittent mist propagation and copolymer moisture barrier systems were compared for rooting using common pachysandra (*P. terminalis* Sieb. & Zucc.), variegated pachysandra (*P. terminalis* 'Variegata'), and euonymus (*E. kiautschovica* Loes.). Percent rooting and root dry weight of both pachysandra cultivars were higher under intermittent mist. More variegated pachysandra rooted than common pachysandra under both propagation systems. Measurements of root development over a 6 week period under both propagation systems indicated that euonymus cuttings rooted more rapidly under intermittent mist than under thermo-blankets; however, cuttings rooted 100 percent under both systems. Copolymer moisture barriers beneath thermo-blankets had no effect on percent rooting or root dry weight of euonymus cuttings.

Index words: microfoam, bottom heat, asexual propagation, euonymus, pachysandra, landscape plants

Introduction

Alternate methods of propagating stem cuttings have gained attention in recent years because of increasing production costs. Numerous species of nursery and landscape plants have been rooted without mist under glass, in cold frames, under outdoor lath and beneath copolymer tents (1,6,7,10,11). But these methods are limited to spring, summer and fall months in the northern and eastern regions. However, thermo-blanket tents have been used successfully to root stem cuttings outdoors throughout the year (3,4,8).

Because of their portability and relative low cost; thermo-blanket propagation systems could possibly make greater use of direct rooting of cuttings (3,8). This would reduce the need for additional greenhouse space while potentially shortening production time and avoiding labor intensive transplanting (10,11).

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The purpose of these studies was to compare outdoor thermo-blanket tent propagation with greenhouse intermittent mist for rooting pachysandra and euonymus stem cuttings and to study the effect of copolymer moisture barriers beneath thermo-blankets.

Materials and Methods

The thermo-blanket tents, positioned on the ground outdoors in full sun, were 46 cm wide x 178 cm long x 25 cm tall (1.5 x 6 x 0.8 ft) made of standard concrete reinforcing mesh covered with a single layer of 0.635 cm (0.25 in) thick microfoam (Ametek, Microfoam Division, 265 Route 202, Chadds Ford, PA 19317) and 4 mil white copolymer (Monsanto Engineered Products Division, St. Louis, MO 63167) had a total light transmission of 19%, similar to that reported by Rizzo *et al.* (9). Air and soil temperatures beneath the thermo-blanket tents and ambient outdoor air were recorded at 2 hour intervals using iron-constantin thermocouples and a Digitec Thermocouple Thermometer (Model #590JC) equipped with a 636 scanner frame and a Digitec Recorder (Model #6140).