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QUALITY OF POTTING SOILS

A Cooperative Study by The Connecticut Agricultural Experiment Station and the Connecticut Department of Agriculture

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Potting soils are widely sold in Connecticut for germinating seedlings, and for growing house plants, and occasionally vegetables. Some are sold as being especially suited for cacti, African violets and other exotic plants thought to require special growth media. Unlike some other agricultural and horticultural items, such as fertilizer and seeds, there are no requirements in Connecticut for labeling of potting soils. Hence, in cooperation with the Connecticut Department of Agriculture, we undertook the present survey of physical and chemical properties of potting soils sold at retail in Connecticut.

Soil placed in a pot does not behave as it does in the field because there is no reservoir of soil beneath the pot to absorb water during wet spells or to release water during dry spells. Therefore, the potting soil must provide large quantities of water from a restricted volume of soil without becoming waterlogged or overly dry. Excess water will leach nutrients from the pot while too little water may cause accumulation of salts. Finally, the small volume of the pot often leads to a dense root system that requires much aeration for exchange of oxygen and carbon dioxide with the atmosphere. To provide adequate air and water, potting soils are usually amended with bulky materials such as peat, bark or wood chips, vermiculite, perlite, and even synthetic materials such as styrofoam or other inert plastics. Indeed, many commercial producers of plants in containers now use potting mixes containing no mineral soil to increase aeration while reducing soil-borne weeds and plant diseases. Thus, the term potting soil or potting mix describes all such mixtures although they may contain no soil.

Plants vary in their ability to grow in pots. Some are tolerant of less than optimum conditions, while others are sensitive. Little information is available on the response of specific house plants, but we assume that the same soils will be favorable or unfavorable for many species. In our study, we limited our growth measurements to: 1) the ability of tomato and lettuce seeds to germinate, and 2) the growth of lettuce seedlings for 30 days without added fertilizer. These observations were then related to physical and chemical characteristics of the potting soils as measured in our laboratories.

MATERIALS AND METHODS

Potting Soils

From June through August, 1982, an inspector of the Connecticut Department of Agriculture purchased potting soils at garden centers, nurseries and retail stores in all areas of the state except northwestern Connecticut. Fifty-one were purchased: 33 were classified as general potting soils, 9 as soil for African violets, 7 as soil for cacti, and 2 as soil for orchids or bulbs. For comparison, we tested two mixes commonly used by commercial growers, as well as a fine sandy loam from the Lockwood Farm in Mt. Carmel.

Chemical Properties

The pH of the samples was measured in a 1:1 paste with water using a standard glass electrode (Peech, 1965). Plant nutrients were determined by the Morgan Soil Test (Lunt, et al., 1950). Soluble salts were measured by the electrical conductivity of a saturated soil-water paste extract (Bower and Wilcox, 1965). Heavy metals (Fe, Mn, Zn, Cu, Ni, Cd) were extracted from the samples with diethylenetriaminepentaacetic acid (DTPA) and analyzed by atomic adsorption spectroscopy (Lindsay and Norvell, 1978). The organic matter content was determined by loss of weight after ignition at 375°C for 16 hours (Ball, 1964), and the state of decomposition of the organic matter was determined by the sodium pyrophosphate technique (McKinzie, 1971).

Physical Properties

The physical properties of potting soils are usually determined by placing a brass cylinder in the large containers used by commercial growers. After harvest or other treatment, the cylinder with soil is removed and the desired measurements made. Alternatively, the soil may be compacted mechanically in the cylinder (Richards et al., 1964). These methods are not well suited to small samples, are tedious, and not highly reproducible.

We devised a method of measuring the necessary properties directly in a 4½″ plastic pot. First, the pot was cut by a bandsaw at a point that left 500 cm³ in the pot base. The two parts of the pot were then united with a wide rubber band providing a water-tight seal. About 600 cm³ of three replicate samples of each mix were placed in the pots and watered three times a week to allow compaction. After a month, the upper part of the pot was removed, the soil above the 500 cm³ volume sliced away, and the upper ring replaced. This provided a known volume of compacted soil in the pot for further measurements.

The infiltration rate, i.e. the inches/hour at which water moves through a saturated soil, was measured by observing the time for 200 ml of water to move through pots that had been saturated with water.

The pots were then allowed to drain freely. After 48 hours, the water present is said to represent container capacity, and the empty pores containing air represent air at container capacity (White and Mastalerz, 1966). Both can be determined by weighing the pot, and expressed as percent of the total volume of soil.

To remove the water held more tightly by the soil, each pot was allowed to dry until a tensiometer placed in the pot indicated a tension of 30 centibars (cb) (This is equivalent to the suction required to remove this water and is about 4.4 lb/in²). Since plants generally show signs of moisture stress at greater tension (Havis, 1980), the amount of water between container capacity and 30 cb is called "available water" for plants. The water and air present can again be obtained by weighing the pot.

Finally, the soil in each pot was dried at 80°C for one week and weighed again. The water between 30 cb and oven dry soil is generally not available for plant growth and is called "unavailable water". The sum of available and unavailable water is the total capacity of the soil for holding moisture. The total porosity or pore space that can be occupied by air or water can also be determined from this weighing. In addition, the bulk density, i.e. the weight of the soil per unit volume, can be calculated and expressed in lb/ft³.

Seed Germination

Twenty-five tomato seeds (*Lycopersicum esculentum* CV September Dawn) were planted in each of three samples of each soil in 4½″ plastic pots. The pots were watered from the top, placed in a standard seed germination chamber (Association of Official Seed Analysts, 1970), and exposed to light for 16 hours per day at 30°C and to dark for 8 hours at 20°C. After 12 days, the numbers of seeds germinated were recorded and expressed as percent germination. The roots were examined microscopically for any obvious plant disease.

In a second test, six seeds of iceberg lettuce (*Lactuca sativa* CV Iceberg) were planted in each of three samples of each soil in trays of cubes for starting seeds. Each cube contained about 65 cm³ of soil. The trays were watered from above, covered with clear plastic and placed in a growth room. After two days the plastic was removed and the trays watered by subirrigation. The seeds were exposed to 24 hours of light at 22°C for 8 days and then to 16 hours of light at 15°C. Germination was recorded after 10 days.

Plant Growth

The iceberg lettuce in the germination tests was thinned to one plant per cube and grown for an additional 20 days in the growth room with 16 hours of light at 15°C. The seedlings were then harvested, shoots and roots were separated, the samples were dried for 24 hours at 75°C, and dry weights were recorded. The fresh roots were examined for disease.

RESULTS

Potting Soils

The names of the potting soils, the manufacturer, and the visible ingredients are tabulated in Table 1. Samples 1 and 10 had weed seeds that germinated during our tests. Live insects were found in sample 1, and many small earthworms were found in sample 25. Sample 9 contained many small stones, and sample 11 contained many small sticks. Three samples (4, 8, 15) were difficult to wet, perhaps because they lacked the wetting agents that are often added to potting soils. In several samples containing bark, the bark tended to float and eventually caused accumulation of coarser materials at the surface of the soil. This separation of particle size within the pot was most pronounced in sample 8. A number of samples were wet when purchased and tended to produce clumps on drying. Because the samples may have become wet after bagging, they are not identified in this report.

Chemical Properties

The chemical analyses are shown in Table 2, where the most obvious feature is the wide range of properties. The pH of the mixes varied from 4.3 to 7.3 (col. 1), and nutrient status (col. 2-7) varied from near deficient (Index 1) to near excess (Index 9)*. Although the concentration of soluble salts (col. 8) is often high in potting soils, our survey did not reveal any with enough salt to be toxic (> 6000 ppm). Similarly, no heavy metals (col. 9-14) were present in concentrations toxic to plants. These analyses were included in our tests because sewage sludge, often high in metals such as Zn, Cu, Ni, and Cd, has been used in commercial potting mixtures. The low concentrations of these metals indicate that sewage sludge was not likely a major ingredient in the mixes we examined.

Physical Properties

As with the chemical analyses, the range of physical properties shown in Table 2 is great. Organic matter (col. 15) varied from less than 10% to more than 90%. Infiltration rates (col. 24) varied from nearly instantaneous (635 in/hr) to nearly impervious (< 5 in/hr). The infiltration rates also varied among replicate samples because infiltration depends on packing, and uniform packing is difficult. The relations among the various physical properties are discussed further below. Details of the statistical analyses of the data are in Appendix I.

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*Index 1 = very low, 2 = low, 3 = medium low, 4 and 5 = medium, 6 = medium high, 7 and 8 = high, and 9 = very high.

Table 1. Potting soils tested.

Sample No.	*Name of Potting Soil*	*Manufacturer*	*Probable Constituents**
	GENERAL POTTING SOILS		
1	Agway Potting Soil	Agway, Syracuse, NY	O.M., P, S
2	Baccto Potting Soil	Michigan Peat Co., Houston, TX	O.M., Sa, V
3	Ball's Potting Soil Mix	Ball's Seed Co., W. Chicago, IL	B, Pt, Sa, V
4	Black Magic Houseplant Mix	The Leisure Group, Carson, CA	P, Pt, W or B
5	Brown's Greenhouse Potting Soil	Brown's Greenhouse, Bloomfield, CT	O.M., P, Pt, Sa, S
6	Burpee Special Potting Mixture	W. Atlee Burpee Co., Warminster, PA	P, Pt, V
7	Bu-T-Gro Potting Soil	Lexington Gardens, Farmington, CT	Pt, S, St
8	Envee Extra Rich Potting Soil	The Leisure Group, Carson, CA	B, O.M.
9	Fafard Potting Soil	Conrad Fafard Co., Springfield, MA	O.M., S, Sa
10	Fertlite Potting Soil	Anderson/Peat Organic Compost, Winter Garden, FL; Old Fort Industries Inc., Fort Wayne, IN	O.M., P, S
11	Flower Show Mix	Brookside Nurseries, Darien, CT	B, O.M., P
12	Gro Potting Soil	Swiss Farms, Philmont, NY	O.M., S
13	Hoffman Potting Mix	A. H. Hoffman Inc., Landsville, PA and Greencastle, IN	O.M., P, Sa
14	Hyponex All Purpose Potting Soil	Hyponex Co., Copley, OH	Pt, S
15	Jiffy Mix Seedstarting and Growing Mix	Carefree Garden Products, N. Chicago, IL	Pt, V
16	Jungle Growth Potting Mix	Jungle Growth, Torrence, CA	O.M., P
17	Ledgcrest Potting Soil	Ledgcrest Greenhouse, Storrs, CT	P, Pt, V
18	Miracle Gro Potting Mix	Sterns Garden Products, Geneva, NY	Pt, V
19	Miracle Soil	Buell's Greenhouse, Eastford, CT	O.M., S
20	Miracle Soil (All Purpose)	Buell's Greenhouse, Eastford, CT	O.M., S, Sa
21	New Era Potting Soil	Clinton Nurseries, Clinton, CT	O.M., P, Pt, S
22	Partridge Soil Compost	Insalaco Nursery Inc., S. Windham, CT	O.M., Sa
23	Premier Potting Soil	Premier Brands Inc., New York, NY	O.M., S, Sa
24	Premier Pro Mix	Premier Brands, New Rochelle, NY	P, Pt, V
25	Primearth Organic Potting Soil	Brookside Nurseries, Darien, CT	O.M., P
26	Stone Age Potting Soil	Stone Age Humus Packing Co., Armonk, NY	O.M., P, S, Sa
27	Super Mix Potting Soil	Super Mix Co., Clinton, CT	O.M., P, V
28	Swiss Farms Potting Soil	Swiss Farms Div., Philmont, NY	O.M., Pt, S
29	Terra-lite Professional Potting Mix	Grace Horticultural Prod., Cambridge, MA	O.M., Pt, V
30	Terra-lite Redi-Earth Potting Soil	Grace Horticultural Prod., Cambridge, MA	Pt, V
31	Terra-lite Tomato and Vegetable Soil	Grace Horticultural Prod., Cambridge, MA	Pt, V
32	Vita Hume Outdoor Planting Mix	Anderson/Peat Organic Compost, Winter Garden, FL; Old Fort Industries Inc., Fort Wayne, IN	O.M., P, S, Sa
33	Woodland All Purpose Mix	Woodland Gardens Corp., Manchester, CT	Pt, S, Sa, V
	AFRICAN VIOLET SOILS		
34	Agway African Violet Soil	Agway, Syracuse, NY	O.M., P, S
35	Bacto African Violet Growing Medium	Michigan Peat Co., Houston, TX	O.M., V
36	Envee Extra Rich African Violet Soil	The Leisure Group, Carson, CA	B, O.M., Pt, V
37	Fafard African Violet Soil	Conrad Fafard Co., Springfield, MA	O.M., S, Sa
38	Hyponex African Violet Potting Soil	Hyponex Co., Copley, OH	Pt, S
39	Jungle Growth African Violet Soil	Jungle Growth, Torrence, CA	O.M., P
40	New Era African Violet Soil	Clinton Nurseries, Clinton, CT	P, Pt, St, V
41	Stone Age African Violet Soil	Stone Age Humus Packing, Armonk, NY	O.M., Pt, Sa, V
42	Super Mix African Violet Soil	Super Mix, Clinton, CT	O.M., P
	CACTUS SOILS		
43	Cactus Mix	Anderson/Peat Organic Compost, Winter Garden, FL; Old Fort Industries Inc., Fort Wayne, IN	O.M., Pt, Sa
44	Fafard Cactus Soil	Conrad Fafard Co., Springfield, MA	O.M., S, Sa
45	Jungle Growth Cactus Mix	Jungle Growth, Torrence, CA	Pt, St, B or W
46	New Era Cactus Soil	Clinton Nurseries, Clinton, CT	O.M., P, V
47	Premier Cactus Soil	Premier Peat Moss Corp., New York, NY	O.M., S, Sa
48	Whitham Nursery Cactus Soil	Whitham Nursery, Bolton, CT	O.M., S, Sa
49	Woodland Cactus and Terrarium Soil	Woodland Gardens Corp., Manchester, CT	O.M., Pt, Sa, St
	BULB AND ORCHID SOILS		
50	Bulb Growing Soil	Premier Brands, New York, NY	O.M., Sa
51	Woodland Orchid Soil	Woodland Gardens Corp., Manchester, CT	B, P, Pt
	COMPARATIVE SOILS		
52	Cheshire Fine Sandy Loam	(Lockwood Farm Soil)	S
53	1-1-1 mix (peat-soil-perlite)	(prepared at CAES)	P, Pt, S
54	Pro-Mix BX	Premier Brands, New Rochelle, NY	P, Pt, V

* S = soil, Sa = sand, O.M. = decomposed organic matter, Pt = peat (peat moss, sphagnum peat), V = vermiculite, P = perlite, St = styrofoam, B = bark chips or shavings, W = wood chips or shavings

Table 2. Chemical and Physical Properties of Potting Soils, and Germination and Growth of Seedlings.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Soil Test Index							mgm/pot					
ID	pH	NO_3	NH_4	P	K	Ca	Mg	Sol. salts, ppm	Fe	Mn	Zn	Cu	Ni	Cd
1	7.3	4	2	8	9	8	7	4222	37.7	0.9	4.6	1.09	0.07	0.17
2	4.4	7	2	5	5	1	3	778	40.4	3.4	1.4	0.32	0.11	0.05
3	5.9	6	2	4	3	1	5	556	6.7	0.3	1.2	0.21	0.05	0.02
4	5.6	1	7	8	2	1	6	200	3.1	1.6	0.2	0.05	0	0
5	6.0	2	5	9	2	8	6	1889	6.1	6.3	1.7	1.24	0	0.01
6	6.3	7	6	8	7	2	6	667	18.4	1.6	0.4	0.14	0	0
7	6.7	3	2	2	2	8	7	222	27.2	0.1	1.7	0.62	0	0.06
8	5.2	5	6	4	2	1	3	533	2.6	0.8	0.2	0.02	0.01	0.01
9	5.5	8	2	4	2	6	6	778	17.4	2.2	2.6	0.65	1.49	0.08
10	5.8	4	2	3	2	6	7	1111	61.4	0.5	0.6	0.06	0.08	0.06
11	7.1	2	2	6	8	6	8	10	1.5	0.6	4.3	2.61	0.16	0.08
12	6.1	2	2	1	1	4	5	1111	111.8	2.0	1.0	1.00	0.02	0.04
13	6.2	6	2	3	1	8	6	556	5.9	0.1	0.6	0.03	0.08	0.05
14	4.4	1	4	1	1	4	3	1111	165.0	6.7	2.6	0.95	0.35	0.09
15	6.3	8	2	7	3	6	6	889	3.3	4.4	0.3	0.10	0.18	0.04
16	4.9	6	6	6	6	1	5	1333	16.5	3.5	0.9	0.12	0	0.02
17	5.4	9	2	8	6	6	4	1700	4.8	1.0	1.1	0.20	0.07	0.02
18	4.8	6	2	6	7	1	5	1111	6.9	1.2	0.7	0.08	0.04	0.01
19	7.0	9	2	6	8	8	6	1889	77.9	2.7	2.0	0.30	0.49	0.15
20	7.0	9	2	6	8	8	6	2111	64.2	1.0	1.6	0.15	0.19	0.14
21	6.3	8	2	5	8	6	4	990	103.1	0.4	2.2	0.29	0	0.04
22	7.1	9	2	9	2	8	6	5110	38.1	0.2	3.3	0.59	0.12	0.04
23	5.1	8	2	7	3	3	5	990	56.6	2.7	0.9	0.07	0	0.03
24	5.8	8	2	8	1	5	4	667	22.3	1.0	0.5	0.06	0.02	0.02
25	6.8	8	2	8	8	8	8	3222	26.0	0.8	5.6	3.91	0.44	0.09
26	5.5	5	2	1	1	2	4	444	63.9	1.0	1.1	0.23	0.36	0.05
27	6.3	8	2	7	5	8	5	1000	100.9	0.5	1.7	0.41	0	0
28	6.0	6	2	1	1	8	5	10	10.5	0.7	1.0	0.68	0.09	0.07
29	6.3	2	2	8	5	3	6	10	1.9	1.9	0.4	0.15	0.11	0.03
30	5.9	8	2	6	2	1	5	778	1.6	2.5	4.4	0.21	1.61	0
31	6.4	8	4	8	4	5	6	2000	1.2	2.4	0.2	0.23	0.12	0.03
32	6.8	6	2	2	2	8	6	333	51.4	0.7	0.5	0.04	0.01	0.03
33	5.2	2	2	9	1	3	2	1120	6.5	2.4	0.7	0.24	0.01	0.01
34	7.1	9	2	8	9	8	7	4444	27.3	0.6	4.5	1.05	0.13	0.18
35	5.2	2	2	2	1	1	4	10	211.2	2.0	1.3	0.24	0.05	0.02
36	6.0	5	6	1	2	1	3	556	1.9	0.8	0.2	0.02	0.03	0
37	4.8	8	2	6	3	2	5	889	23.3	4.0	0.5	0.04	1.48	0.03
38	4.7	2	4	2	1	6	5	1333	185.7	5.7	2.5	1.33	0.55	0.09
39	4.6	7	8	8	6	1	3	1444	22.5	6.6	1.4	0.07	0.05	0.02
40	6.3	7	2	3	8	7	4	889	85.2	0.2	1.7	0.17	0	0.04
41	4.8	6	2	2	4	2	4	444	51.6	3.5	1.3	0.17	0.35	0.06
42	6.3	9	2	8	9	8	6	1667	57.0	0.2	2.4	0.16	0	0.07
43	6.5	8	2	4	2	8	4	667	30.7	1.3	0.8	0.15	0.07	0.05
44	5.1	8	2	5	4	3	2	889	15.4	3.6	0.5	0.02	1.52	0.06
45	4.3	8	7	7	6	1	3	1667	22.8	7.7	1.2	0.08	0.04	0.02
46	6.4	8	2	5	8	7	6	1667	84.1	0.2	2.4	0.23	0.14	0.07
47	5.4	4	2	8	2	8	5	778	28.8	8.3	0.5	0.17	0.16	0.01
48	6.5	8	9	9	8	8	5	1444	4.5	1.0	0.6	0.02	0.19	0.02
49	5.4	3	2	8	1	3	2	889	7.9	2.8	0.7	0.14	0.12	0
50	5.5	2	2	8	1	8	4	889	2.4	1.2	4.3	1.07	0.19	0.02
51	5.9	2	2	8	8	4	4	556	2.3	3.3	1.4	0.26	0.04	0.03
52	6.3	8	2	4	8	5	5	1556	16.3	0.5	17.7	1.73	0.03	0.06
53	6.4	6	3	6	4	6	5	667	8.8	0.8	8.5	0.47	0.01	0
54	6.3	8	2	7	2	3	4	167	1.4	0.5	1.1	0.21	0.04	0

Table 2. **Continued.**

ID	15 % O.M.	16 O.M. state	17 Cont. air	18 Avail. H_2O	19 Unavail. H_2O	20 Total H_2O	21 B.D.	22 Pores, %	23 Air, 30 cb	24 Infil., in/hr	25 Tom. germ.	26 Let. germ.	27 Let. yield
1	37.6	2	11.4	21.9	44.2	66.1	26.2	77.5	33.3	9.4	68.0	27.7	0.09
2	35.5	3	8.6	50.0	29.6	79.6	16.9	88.2	58.6	39.1	64.0	88.9	0.14
3	44.8	4	12.0	50.3	23.9	74.2	11.9	86.2	62.3	91.4	48.0	83.3	0.14
4	78.7	4	17.9	48.6	14.0	62.6	6.9	80.1	66.1	31.9	65.2	11.1	0
5	11.8	1	6.9	44.1	19.2	63.3	32.5	70.2	51.0	22.9	65.2	88.9	0.14
6	36.7	4	12.8	60.2	20.2	80.4	7.5	93.3	73.0	29.1	58.8	66.6	0.25
7	10.8	1	7.6	46.6	13.7	60.3	37.5	67.9	54.1	55.0	69.2	77.8	0.08
8	93.6	4	29.6	45.4	9.3	54.6	7.5	84.3	75.0	635.0	49.2	33.3	0.10
9	17.6	1	7.2	45.4	22.1	67.5	34.3	74.7	52.6	37.4	72.0	77.8	0.26
10	39.4	2	5.8	43.3	35.7	79.1	17.5	84.9	49.1	14.9	68.0	88.9	0.10
11	39.8	2	25.9	34.7	23.3	58.0	16.2	84.0	60.7	120.0	64.0	55.6	0.03
12	17.9	1	6.9	29.4	29.4	58.8	45.6	65.7	36.3	13.9	72.0	77.8	0.09
13	28.0	2	6.6	50.1	23.1	73.2	26.9	79.8	56.7	18.4	64.0	88.9	0.11
14	33.0	2	10.5	38.3	29.3	67.5	28.7	78.0	48.8	15.8	54.8	72.2	0.08
15	35.8	3	16.0	57.4	19.0	76.3	8.1	92.4	73.4	65.4	68.0	77.8	0.28
16	83.1	4	11.4	53.5	18.6	72.1	12.5	83.5	64.9	72.1	76.0	44.4	0.09
17	48.1	4	11.9	59.3	19.3	78.6	7.5	90.4	71.2	68.3	72.0	66.6	0.18
18	50.5	4	8.1	60.1	22.7	82.8	10.0	90.9	68.2	64.7	72.0	55.6	0.23
19	14.9	1	5.8	32.1	29.0	61.1	47.5	66.9	37.9	14.9	70.8	61.2	0.25
20	13.0	1	5.9	35.3	28.5	63.8	42.5	69.7	41.2	21.4	54.8	100.0	0.24
21	28.5	2	5.5	36.2	31.2	67.4	31.8	72.9	41.7	10.0	65.2	88.9	0.14
22	29.2	2	16.7	33.7	32.9	66.6	23.7	83.4	50.5	73.8	73.2	88.9	0.14
23	35.2	2	6.6	42.9	31.5	74.4	23.7	81.0	49.5	19.6	52.0	88.9	0.23
24	54.1	4	13.2	54.8	21.6	76.3	8.7	89.5	68.0	20.0	60.0	61.2	0.31
25	28.5	2	7.0	43.5	27.6	71.1	21.2	78.1	50.5	27.2	66.8	77.8	0.19
26	9.1	1	6.2	26.2	28.6	54.8	56.2	61.0	32.4	4.2	62.8	44.4	0.05
27	37.8	2	6.0	35.9	34.0	69.8	28.7	75.9	41.9	8.7	66.8	94.5	0.14
28	26.2	2	7.0	36.2	32.4	68.5	32.5	75.5	43.2	39.4	68.0	72.2	0.06
29	34.0	4	11.7	59.8	18.8	78.6	10.6	90.3	71.5	149.7	66.8	83.3	0.17
30	18.4	1	15.0	55.4	23.3	78.7	8.7	93.7	70.4	137.0	68.0	94.5	0.15
31	25.2	4	14.5	59.0	21.9	80.9	7.5	95.4	73.5	91.6	66.8	94.5	0.51
32	27.2	2	6.8	43.7	31.0	74.7	23.7	81.5	50.5	23.6	65.2	83.3	0.09
33	25.2	4	17.1	52.0	15.0	67.0	15.6	84.2	69.1	137.7	58.8	66.6	0.11
34	41.3	2	8.2	40.0	34.6	74.6	21.9	82.8	48.2	30.1	65.2	77.8	0.27
35	81.5	2	21.9	26.5	39.2	65.7	11.2	87.6	48.4	39.1	76.0	66.6	0.07
36	83.4	4	22.0	57.4	9.6	67.0	8.7	89.0	79.4	142.0	74.8	72.2	0.08
37	19.3	1	5.6	42.6	25.3	67.9	35.6	73.5	48.2	13.1	64.0	83.3	0.22
38	25.8	2	7.7	35.0	29.9	64.9	32.5	72.7	42.7	26.7	70.8	61.2	0.11
39	80.3	4	11.4	54.7	18.9	73.6	13.1	85.0	66.1	56.5	76.0	66.6	0.12
40	30.1	2	6.3	40.4	31.3	71.7	28.7	78.1	46.7	28.4	57.2	50.0	0.15
41	11.1	1	7.3	36.6	25.7	62.3	39.3	69.6	43.9	11.0	56.0	72.2	0.08
42	32.0	2	5.2	38.1	30.9	68.9	30.0	74.1	43.3	25.5	68.0	83.3	0.15
43	18.5	1	6.1	38.9	23.9	62.8	40.6	68.9	45.0	13.5	65.2	83.3	0.19
44	9.5	1	6.2	38.9	18.4	57.3	49.3	63.5	45.1	12.4	52.0	83.3	0.23
45	81.3	4	9.2	55.9	18.5	74.4	13.7	83.6	65.1	32.8	70.8	61.2	0.17
46	26.7	2	5.3	38.7	29.2	67.8	34.3	73.1	44.0	19.7	70.8	55.6	0.11
47	26.8	2	6.3	47.3	23.1	70.4	32.5	76.4	53.6	28.8	73.2	88.9	0.07
48	10.1	1	6.9	41.2	22.3	63.5	46.8	70.4	48.2	41.5	72.0	66.6	0.13
49	10.4	1	10.6	48.3	12.4	60.7	30.0	71.3	58.9	82.1	58.8	88.9	0.08
50	25.8	2	7.7	44.3	30.2	74.5	25.0	82.1	52.0	22.8	62.8	83.3	0.05
51	64.1	4	22.3	34.2	21.7	55.9	10.6	84.2	62.5	283.3	65.2	61.2	0.04
52	3.4	1	4.4	22.9	18.1	41.0	78.7	45.4	27.3	3.3	45.2	5.6	0
53	8.7	1	8.5	46.0	15.2	61.2	32.5	69.7	54.5	30.7	65.2	38.9	0.12
54	51.3	4	14.6	60.2	15.9	76.1	6.9	90.7	74.8	133.7	57.2	72.2	0.19

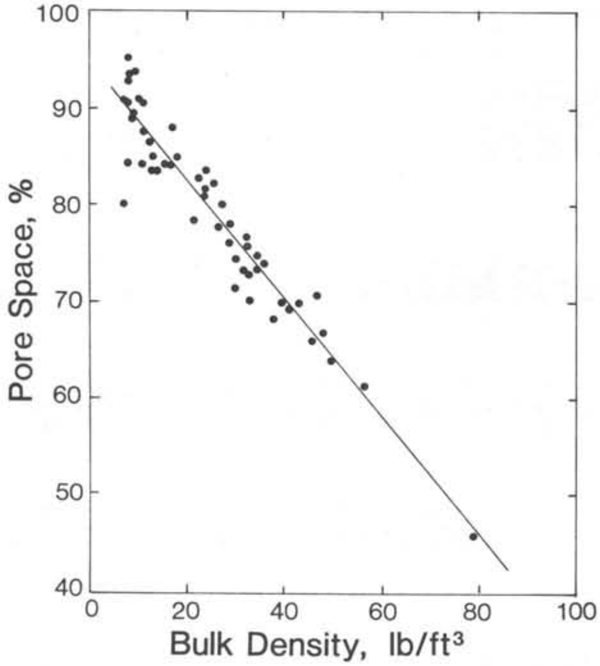

Figure 1. Pore space versus bulk density of potting soils.

Germination and Growth Tests

The germination of tomato and lettuce and the growth of lettuce in the potting mixes are also shown in Table 2. Germination of tomato seeds (col. 25) under the nearly optimum conditions was uniform, with an average germination of 64.9% and a standard deviation of ± 7.4%. In a standard germination test, this lot of tomato seed had 75% germination. The lettuce germination (col. 26) and growth (col. 27) will be related to physical and chemical properties of the mixes in the next section. The only disease observed was a root-rotting fungus, *Pythium* sp, in the water-logged farm soil.

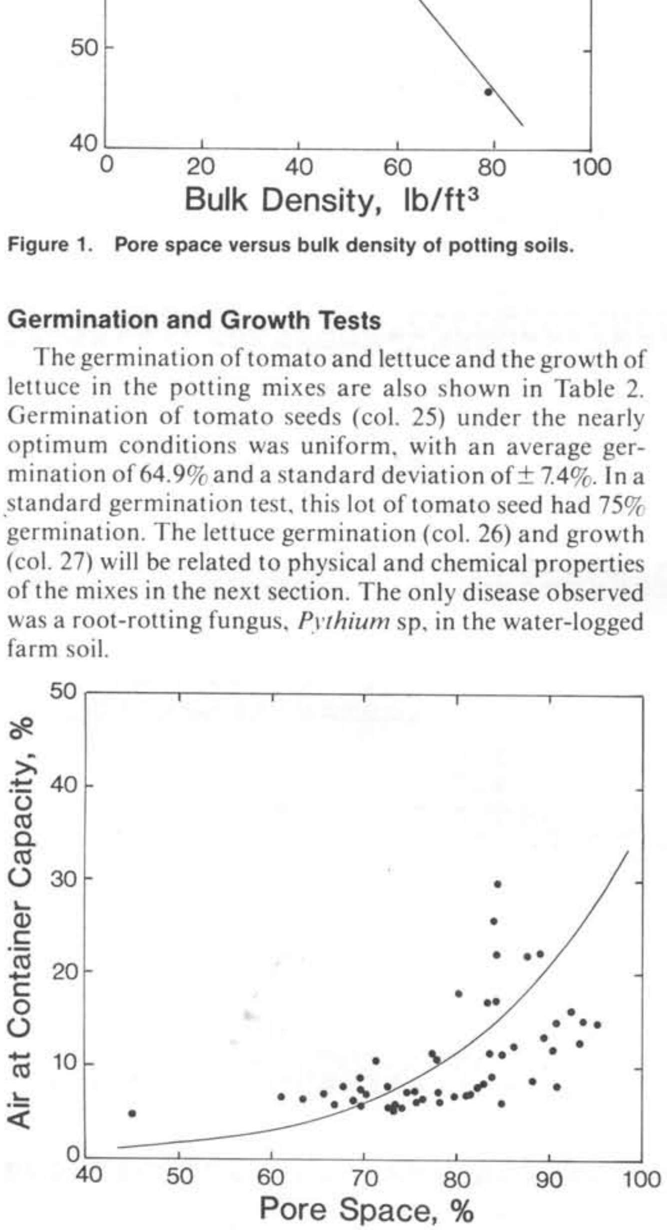

Figure 2. Air at container capacity versus pore space of potting soils.

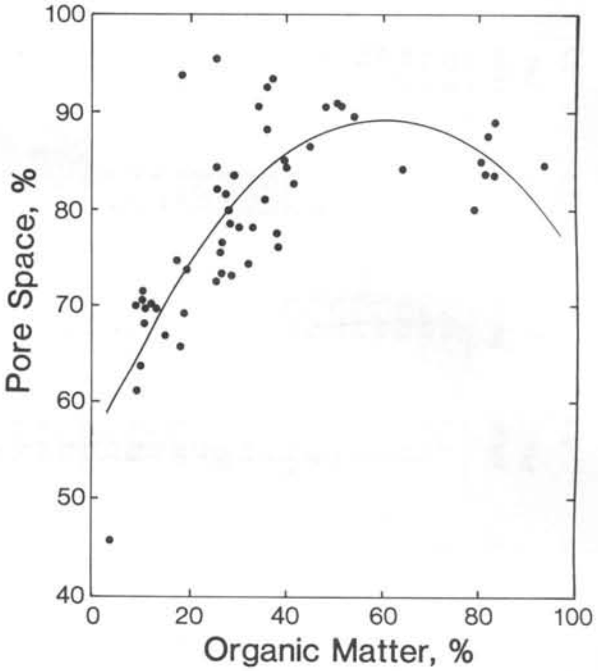

Figure 3. Pore space versus organic matter of potting soils.

DISCUSSION

Adequate soil aeration is thought to be an important determinant of quality potting soils, and is achieved by adding materials that increase pore space. Figure 1 shows that the total pore space of the mixes (col. 22) is determined by their bulk density (col. 21): mixes that are light in weight are likely to be more porous than heavier mixes.

Soil aeration is most likely to become limiting following watering to container capacity. Figure 2 shows that air at container capacity (col. 17) increases logarithmically as pore space (col. 22) increases. Thus, the lighter mixes can be expected to have the most air at container capacity. The effect of high bulk density can be seen in the farm soil (No. 52, Table 2) that weighs 78.7 lb/ft³, has less than 50% pore space and only 4.5% air at container capacity.

Although the amount of organic matter in a mix (col. 15) is often considered a good indicator of pore space (col. 22), our results show that mixes containing more than about 50% organic matter may actually have less pore space (Fig. 3). This is due to an accompanying decrease in inorganic bulking agents such as vermiculite, perlite, and styrofoam that apparently are more effective than organic matter in increasing aeration. The decomposition of the organic matter (col. 16) is also important (Fig. 4). Type 1 indicates mixes that contain less than about 20% organic matter and hence are high in mineral soil, sand, or other inorganic constituents. Type 2 organic matter is known as "sapric" and is generally fine-textured, black in color, and highly decomposed; swamp muck is a typical example. Type 4 is known as "fibric" and is usually coarse-textured, brown in color, and not highly decomposed; sphagnum peat moss and bark chips are good examples. Type 3 is intermediate and known as "hemic"; only two of our samples were in this category. Figure 4 shows that pore space is low in mixes where organic matter is highly decomposed.

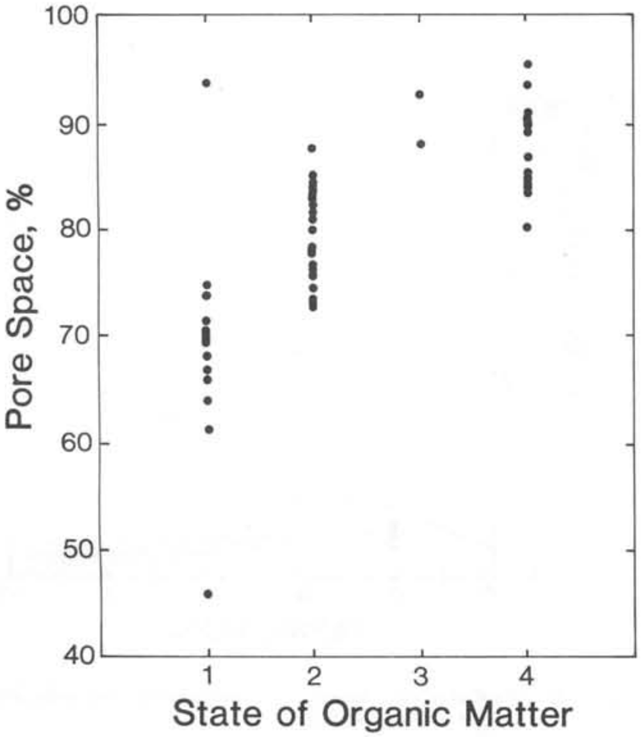

Figure 4. Pore space versus state of organic matter of potting soils. 1 = inorganic, 2 = sapric, 3 = hemic, 4 = fibric.

The relation between water and air in mixes is critical. Total (col. 20) and available (col. 18) water-holding capacity increase linearly with increasing pore space (Fig. 5). This is most likely due to the large amounts of peat or vermiculite in the highly aerated mixes adding aeration and also holding many times their own weight of water. The relation between air and plant available water is slightly different than that between air and pore space: Figure 6 shows that available water (col. 18) tends to reach a maximum in the range of 10 to 20% air at container capacity (col. 17). This coincides with the range in air at container capacity generally thought to be optimum (Conover, 1967).

The ultimate test of a potting soil is its ability to support the germination and growth of plants. Long growth of a wide variety of plants was impractical for this survey; hence, our tests were limited to the experiments with lettuce. Although our results may not be identical with the response of mature plants growing in pots rather than in cubes for starting seed, we believe that they indicate the relative quality of the mixes.

Analyses of the germination of lettuce indicate that there were statistically significant differences in germination among the different mixes. Seeds germinated best in mixes with the highest total water holding capacity. Other properties exerted little influence, confirming the general expectation that seeds germinate best in moist environments.

Yields of lettuce also varied widely as shown by the range of growth in representative mixes in Figure 7. The best predictors of yield (col. 27) were soil-test nitrate (Fig. 8) and available water. As nitrate and available water increase, yield also increases. In fact, nearly half the variability in yield was accounted for by these two measurements combined.

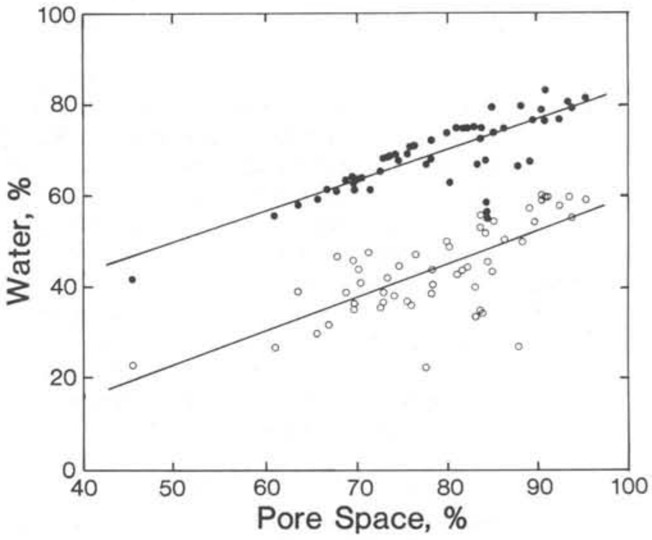

Figure 5. Total (•) and available (◦) water versus pore space of potting soils.

Several factors thought to affect plant growth did not affect the lettuce seedlings but deserve brief comment. Despite the acidity or low pH of many of the mixes, there was no significant correlation between pH and yield. Acidity affects growth in two ways: one is the direct effect of the hydrogen ion, and the other is the indirect effect of acidity on available nutrients or toxic elements in the soil. In a classic experiment, Arnon and Johnson (1942) showed that tomato, lettuce and Bermuda grass grew well in nutrient solutions between pH 4 and 8 provided adequate nutrients were supplied. Thus, direct effects of acidity would not be expected in our tests. In an acid Connecticut soil, however, tomatoes exhibited distinct signs of metal toxicity at pH 5.0 or less (Peaslee and Frink, 1969). This is in agreement with general agronomic experience that most plants grow best between pH 5.5 and 7.0. The lack of metal toxicity in these potting soils with pH as low as 4.3 may be

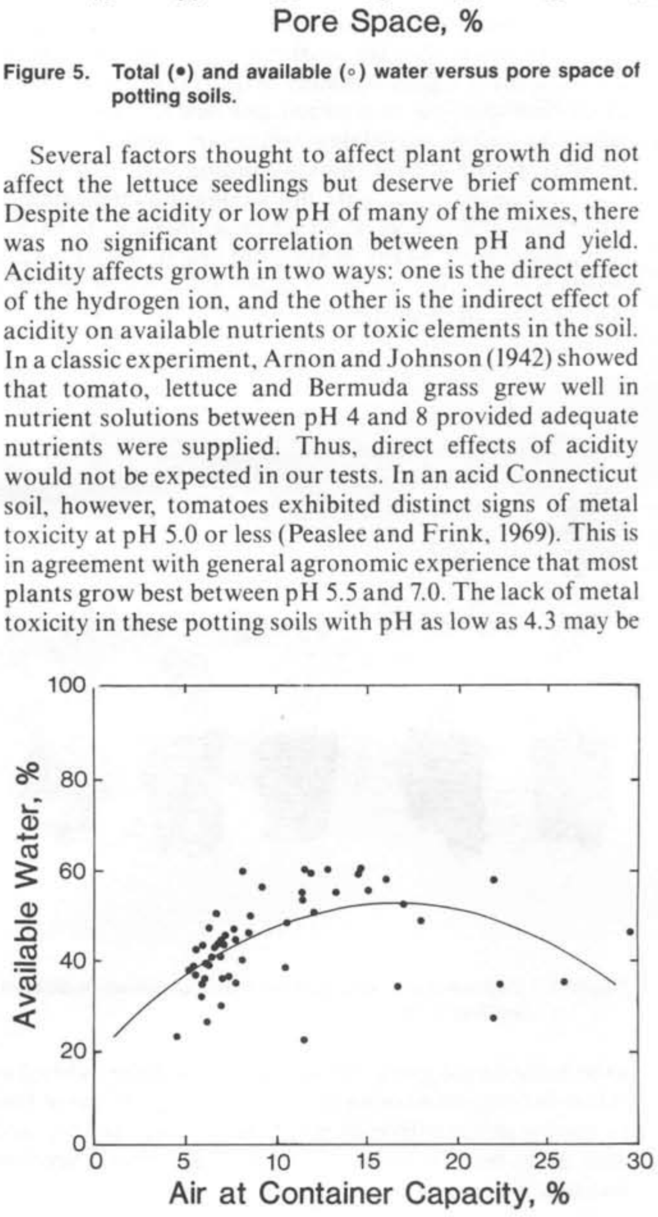

Figure 6. Available water versus air at container capacity of potting soils.

due in part to their higher content of organic matter, which has the ability to react with metals and reduce their toxicity (Lucas and Davis, 1961).

We also measured the pH of the mixes after the growth studies because limestone may take months to react fully in soil. In 17 samples, the pH had declined as much as 0.7 units, 8 remained unchanged, and 29 increased by as much as 1.1 units. However, most changes in pH were slight. Since fertilizer reactions and plant growth are acidifying processes, mixes with higher pH are probably more desirable, although no direct effects were observed.

Soluble salts are often thought to be a problem in potting soils, but we observed no correlation of soluble salts with yield. Since a few mixes had soluble salts ranging from 3000 to 5000 ppm, additional fertilizer could increase salts to toxic levels in these mixes unless they are heavily watered.

CONCLUSIONS

The physical, chemical and biological properties that we measured show that the quality of potting soils sold in Connecticut is highly variable. Mixes ranged from heavy muck-like soils low in aeration and nearly impervious to water, to mixes containing sphagnum peat moss, vermiculite, perlite or bark chips promoting high aeration and good drainage. Some were not sterilized as indicated by weed seeds and insects, although none appeared to harbor plant pathogens. Many mixes were low in fertility, while others were fertile. The pH of many mixes was lower than that thought to be optimum. Few differences appeared to exist between the general potting soils and those labeled as mixes for cacti or African violets. Lettuce germinated best in porous mixes with high moisture holding capacity, and also grew best in these mixes provided that abundant fertilizer was present.

Figure 7. **Lettuce seedlings after four weeks of growth in different potting soils.**

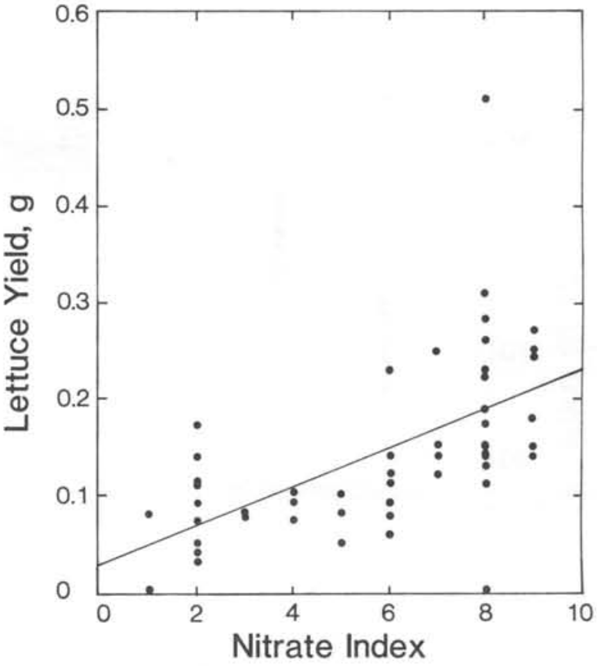

Figure 8. **Yield of lettuce shoots versus nitrate in potting soils, dry weight of three replicates.**

REFERENCES

Arnon, D. I. and C. M. Johnson. 1942. Influence of hydrogen ion concentration on the growth of higher plants under controlled conditions. Plant Physiol. 17:525-539.

Association of Official Seed Analysts. 1970. Rules for testing seed. Proc. Assoc. Official Seed Analysts 60(2):1-116.

Ball, D. F. 1964. Loss-on-ignition as an estimate of organic carbon in non-calcareous soil. J. Soil Sci. 15:84-92.

Bower, C. A. and L. V. Wilcox. 1965. Soluble salts, pp. 933-940. *In* Methods of Soil Analysis, Part II, C. A. Black (Ed.). American Society of Agronomy, Madison, WI.

Conover, C. A. 1967. Soil mixes for ornamental plants. Florida Flower Grower 4(4):1-4.

Havis, J. R. 1980. Container moisture state and stomatal resistance in nursery plants. Hortscience 15(5):638-639.

Lindsay, W. L. and W. A. Norvell. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42:421-428.

Lucas, R. E. and J. F. Davis. 1961. Relationships between pH values of organic soils and availabilities of 12 plant nutrients. Soil Sci. 92:177-182.

Lunt, H. A., C. L. W. Swanson, and H. G. M. Jacobson. 1950. The Morgan Soil Testing System. Bulletin 541. The Connecticut Agricultural Experiment Station, 60p.

McKinzie, W. 1971. Field tests for organic soils. *In* Report of Committee on Histosols, Attachment 3. Proceedings of National Technical Work-Planning Conference of the Cooperative Soil Survey, Charleston, SC. USDA Mimeo Rep. 5p.

Peaslee, D. E. and C. R. Frink. 1969. Influence of silicic acid on uptake of Mn, Al, Zn, and Cu by tomatoes (*Lycopersicum esculentum*) grown in acid soil. Soil Sci. Soc. Am. Proc. 33:569-571.

Peech, M. 1965. Hydrogen Ion Activity, pp. 914-925. *In* Methods of Soil Analysis, Part II, C. A. Black (Ed.). American Society of Agronomy, Madison, WI.

Richards, S. J., J. E. Warneke, A. W. Marsh and F. K. Aljibury. 1964. Physical properties of soil mixes. Soil Sci. 98:129-133.

White, J. W. and J. W. Mastalerz. 1966. Soil moisture as related to "Container Capacity". Proc. Am. Soc. Hortic. Sci. 89:758-765.

Appendix I. STATISTICAL ANALYSES

The physical properties of the mixes, as well as the germination and growth of seedlings were determined on three samples. Because these data were variable, they were averaged before statistical analyses. The soil tests for pH, nutrients, and soluble salts were performed in duplicate. Other measurements reported were analyses of single samples. For this reason, the figures and accompanying statistical analyses will show less variability than if all observations were plotted, rather than their means.

Pore Space and Bulk Density, Figure 1.

The relation between percent pore space (PS) and bulk density (BD, lb/ft^3) is given by:

$$BD = \rho(100 - PS)/100 = \rho - \rho(PS)/100$$

where ρ is the mean specific gravity of the components of the mix. We analyzed our data by regression analysis and found:

$$BD = 142.4 - 1.48\ (PS)$$

with coefficient of determination $r^2 = 0.91$. However, for mixes with bulk densities less than about 20 lb/ft^3, there is significant variability around the fitted line. For example, for the mix furthest below the line ($PS \cong 80$, $BD \cong 8$), the specific gravity is about 39 lb/ft^3. For the mix furthest above the line ($PS \cong 95$, $BD \cong 8$), the specific gravity is 156 lb/ft^3. The samples above the line are generally high in vermiculite, while those below the line are high in organic matter.

Air at Container Capacity and Pore Space, Figure 2.

The relation between air (AIR) at container capacity and pore space reflects the number of large pores relative to all pores in a mix. Our data were best fit by an equation of the form:

$$\log AIR = -9.54 + 5.55 \log PS$$

with $r^2 = 0.41$. The variability is relatively large since samples with high total pore space need not necessarily have many large pores. In this case, for samples with pore space of 85% or more, the samples below the line are high in organic matter.

Pore Space and Organic Matter, Figure 3.

The relation between pore space and organic matter (OM) is clearly non-linear and could be fit with a logarithmic function. The data suggest that pore space declines at high organic matter content; hence, they were fitted with a polynomial of the form:

$$PS = 56.26 + 1.095\ OM - 0.0090\ (OM)^2$$

with $r^2 = 0.62$. The samples with organic matter content > 80% are generally those falling below the line in Figure 1.

Pore Space and Decomposition of Organic Matter, Figure 4.

The state of decomposition of the organic matter was given a rank score that is not a quantitative factor. The mean pore space for inorganic Type 1 was 68.9%, for sapric Type 2 was 79.0%, and for fibric Type 4 was 87.5%.

Total and Available Water versus Pore Space, Figure 5.

In contrast to the rather complex relation between air and pore space (Figure 2), the relations between water and pore space are quite straightforward. For total water (TW) and pore space:

$$TW = 15.7 + 0.667\ (PS)$$

with $r^2 = 0.62$. For available water (AW) the relation is:

$$AW = -13.4 + 0.727\ (PS)$$

with $r^2 = 0.48$. The greater variability in available water is consistent with our observations of air and pore spaces: mixes with high total pore space do not necessarily have many large pores.

Available Water and Air at Container Capacity, Figure 6.

The relation between available water and air is quite variable but could be fit with a polynomial of the form:

$$AW = 19.97 + 3.926\ (AIR) - 0.1208\ (AIR)^2$$

with $r^2 = 0.27$. Because the correlation is low and the meaning of this relation is not straightforward, the line is not shown.

Germination of Lettuce, Figure 7.

Only two properties of the mix were of predictive value: total water and air at container capacity. If the two are combined in multiple linear regression analysis the result is:

$$\%GERM = 4.50 + 1.09\ (TW) - 0.80\ (AIR)$$

with multiple coefficient of determination $R^2 = 0.25$. The physical interpretation is that seeds germinate best in a moist environment and that drying caused by increased air space is detrimental. This does not mean, however, that the mix should be water-logged: seedlings failed to germinate in the farm soil with only 4.4% air at container capacity.

Yield of Lettuce and Nitrate, Figure 8.

The relation between yield of lettuce (YL) in grams per three samples and nitrate soil test (NO_3) is reasonably linear and is given by:

$$YL = 0.025 + 0.02\ (NO_3)$$

with $r^2 = 0.34$.

Yield of Lettuce and Available Water.

The relation between yield and available water is poor, with $r^2 = 0.16$. If total water is used, $r^2 = 0.25$. When nitrate and water are combined in multiple linear regression, available and total water are equally good predictors:

$$YL = -0.098 + 0.019\ (NO_3) + .0030\ (AW)$$

with multiple coefficient of determination $R^2 = 0.45$.