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VARIATION AMONG HEALTHY AND DETERIORATING ASPEN CLONES

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RESEARCH SUMMARY

Differences between healthy and deteriorating aspen (*Populus tremuloides* Michx.) clones were studied by investigating clonal variation in growth rates, growth habits, and vegetative propagation. In contrast to well stocked healthy clones, deteriorating clones were characterized by a low density of stems which were younger and smaller in size and had poorer form and higher crown ratios than stems in healthy clones. Site index was significantly higher in healthy clones than in deteriorating clones; the environmental characteristics of sites occupied by the clones, however, showed no important differences. There were no significant differences between healthy and deteriorating clones in suckering ability of excised roots or rooting ability of sucker cuttings. Comparisons of growth rates, stem form, and branching characteristics between 2-year-old ramets of deteriorating and healthy clones growing in containers indicated no inherent differences in early growth and development.

CONTENTS

INTRODUCTION

Previously, Schier (1975) described the general pattern of deterioration in western aspen (*Populus tremuloides* Michx.). Poorly stocked deteriorating clones were found growing adjacent to well-stocked mature healthy clones. The occurrence of deteriorating and healthy clones on similar sites indicated that the age at which aspen ramets begin to die is genetically controlled. It was noted that deteriorating clones were visually distinguishable from healthy ones. Their stems tended to be shorter and branchier, and to have poorer form than the stems of healthy clones. Thus it appeared that the longevity of aspen ramets was correlated with various morphological characteristics.

A major factor that probably contributes to variation in timing and rate of decline of an aspen genotype is site quality. The ramets of a clone will probably start deteriorating earlier on a poor site than a good one. In the Lake States, it has been well documented that environmental variables have a significant effect on aspen longevity (Kittridge 1938; Graham and others 1963; Shields and Bockheim 1978).

The objectives of this research were (1) to determine if there are inherent differences between healthy and deteriorating clones in morphological characteristics and capacity for vegetative propagation, and (2) to determine if site quality is a factor contributing to the deterioration of aspen clones.

METHODS

Clone Selection

Ten healthy and 10 deteriorating clones were selected in Logan Canyon on the Wasatch National Forest east of Logan, Utah. The criteria used for selecting these two types of clones were the same as those used in the earlier study (Schier 1975). Clones were distinguished by sex, leaf, stem, branch, and phenological characteristics (Barnes 1969). Ramets of deteriorating clones were characterized by relatively high mortality and low basal areas. Ramets of healthy clones were mature, had high levels of stocking, and no unusual mortality. No attempt was made to pair each deteriorating clone with a healthy one as was done previously. Clones that showed a wide range in the expression of phenotypic characteristics were selected.

Clone Descriptions

Stand data for each clone were obtained from randomly located 0.025-acre (0.01-ha) circular plots. Numbers of plots were determined by clone size and variations in stem density. For each living ramet with a d.b.h. 0.78 inch (2 cm) and larger, diameter at breast height, crown ratio, and relative bole length were recorded. Crown ratio (to nearest 10 percent) is the portion of the tree bole that supports living green foliage. Relative bole length (4 classes: 1, 90 to 100 percent; 2, 75 to 90 percent; 3, 50 to 75 percent; and 4, <50 percent) is the length of the longest straight section of a tree expressed as a percentage of the length of straight section that would be possible if there were no deformities such as forking, crook, and sweep. The number of standing dead stems (0.78 inch d.b.h. [2 cm] and larger) occurring on each plot was recorded. Five trees within the dominant and codominant crown classes were randomly selected for height measurement and age determination.

Photographs of each clone were taken from permanent photo points. They were taken in the autumn after leaf fall to emphasize ramet density, stem form, and branching characteristics.

Sucker regeneration (stem d.b.h. 0.78 inch [<2 cm]) was determined from 5.38 ft^2 (0.5 m^2) circular plots located at 19.7-ft (6-m) intervals along transect lines 39.4 ft (12 m) apart.

Environmental Variables

Environmental variables in all clones were evaluated to determine if differences in site conditions could have accounted for the phenotypic differences between healthy and deteriorating clones. Physiographic features recorded at each clone's location were elevation, aspect, slope percent, slope position, and exposure. Aspect was transformed to the sine of the azimuth using the formula of Beers and others (1966). Values range from 0 for a southwest exposure to 2 for a northeast. Slope position was coded from 1 to 5 using a method similar to that of Bowersox and Ward (1972). Coded values were determined by slope curvature and distance from ridge summit. The exposure of clones to wind and wind-related influences was estimated using a scale of 1 (exposed) to 5 (sheltered) as described by Fralish and Loucks (1975).

Soil characteristics were determined from bulk soil samples taken with a soil auger at depths of 0 to 7.9 inches (0 to 20 cm) and 31.5 to 39.4 inches (80 to 100 cm) at four randomly located points in a clone. Samples from corresponding depths were composited. Soil samples were air dried, hard structural peds crushed, and sieved through a 0.08-inch (2-mm) screen. Soil pH was measured in a 1:1 soil and water mixture with a glass electrode. Cation exchange capacity was determined by sodium acetate saturation, ammonium acetate displacement, and measurement of the amount of sodium ion in the leachate by atomic absorption. Soil phosphorus was extracted with sodium bicarbonate and determined colorimetrically. "Exchangeable" sodium, calcium, magnesium, and potassium were extracted with ammonium acetate and determined by atomic absorption. Organic carbon was determined by digestion with hot chromic acid. Total nitrogen was measured by the macro-Kjeldahl method. Particle size distribution was analyzed with a hydrometer.

Suckering Ability

Root segments were collected in September 1974, July 1975, and May 1976 to determine the ability of the clones to produce suckers. During each of these times, it was necessary to make collections over a period of 5 days. On each day during this period, roots from two deteriorating and two healthy clones were collected. One to two roots in the upper 19.7 inches (50 cm) of soil were excavated at 30 or more locations in a clone to sample the range in suckering capacity. Thirty root segments (3.94 inches [10 cm] x 0.39 to 0.78 inches [1 to 2 cm]) were randomly selected from the roots of each clone, rinsed in tap water, andplanted horizontally 0.59 inches (1.5 cm) deep in moistened vermiculite. Root cuttings from each of the four clones were subdivided into six groups of five cuttings each. The resulting 24 groups were randomly distributed among four plant trays (six groups per tray). The trays were placed on a bench in a greenhouse having a temperature range of approximately 59° F (15° C) nights to 77° F (25° C) days. After root cuttings from all 20 clones had been planted, the trays were randomized on the greenhouse bench. Forty-two days after the root segments of a clone had been collected, they were lifted and the number of suckers taller than 5 mm and the height of the tallest sucker were recorded for each segment.

From the range of root diameters (0.39 to 0.78 inches [1 to 2 cm]) used to determine suckering ability, 20 root sections were randomly selected from each clone for determination of mean root age.

Rooting Ability

Suckers from roots collected in September 1974 were the source of cuttings used for determining clonal variation in the ability to initiate adventitious roots. Sixty of the tallest suckers were severed from the root segments of each clone at the root surface. The base of each cutting was inserted to a depth of 0.78 inch (2 cm) in a perlite:vermiculite (1:1) medium. Then the cuttings were placed under an intermittent mist in a greenhouse for 21 days (temperature range, 59°-77° F [15°-25° C]). Each

clone was represented by six randomized rows of 10 cuttings each. When the cuttings were lifted, the number of roots and length of the longest root on each cutting was recorded.

Growth Characteristics of the Ramets

Cuttings from suckers originating from roots collected in May 1976 were rooted and planted in containers during the last week in July (sucker production, 6 weeks; and rooting, 3 weeks). The rooting procedure was similar to that described above except that the sucker cuttings were treated with indolebutyric acid (IBA) to enhance rootings. Details of the entire procedure for vegetatively propagating aspen have been described by Schier (1978).

From each clone, 30 cuttings having the best root systems were planted in tubes, 2.5 x 10.0 inches (6.4 x 25.4 cm), with a vermiculite-peat moss (1:1) potting mix. Each ramet received 1/4 tsp of Scott's Shrub and Tree Fertilizer. The containerized aspen were placed on a greenhouse bench in a completely randomized design and were periodically watered. To maximize ramet growth, day lengths were extended from August 1 to October 26 with artificial lighting. Although most ramets continued to put on top growth during long days, a significant number that had set bud during the rooting period remained dormant. On October 26, the ramets were moved to a "cold" compartment in the greenhouse where the temperature was maintained between 35.6° F (2° C) and 50.0° F (10° C). This temperature has been found to satisfy the cold requirements of Utah aspen as indicated by a normal spring bud break.

During the second week of April 1977, prior to flushing, the ramets were transplanted into 1 gal (3.8 liter) pots. The potting medium was a 3:2 peatmoss-sand mixture. The plants were given 1/2 tsp Scott's fertilizer and moved outside to a lathhouse (50 percent shading) where they were completely randomized on benches. The plants were watered twice weekly except when natural precipitation was adequate. Fertilizer was applied every 4 to 6 weeks. Plant pests such as red spider mites, cottonwood beetles, aphids, and powdery mildew were controlled by insecticides (two sprayings) and fungicides (three sprayings).

In October 1977, counts were made of the numbers of ramets surviving and stem and crown characteristics measured. This included annual height growth, number and length of laterals, occurrence of forking, and stem form (scored: 1 = straight; 5 = very crooked).

In May 1978, the 2-year-old ramets were planted in a common garden. The growth characteristics of the clones will be monitored over a 10-year period to determine whether the inherent differences between healthy and deteriorating clones become more definitive as the ramets grow in size and morphological complexity.

Statistical Analysis

Analysis of variance was used to analyze the data from the suckering and rooting tests. All other data were analyzed by unpaired t-tests.

RESULTS

Descriptions of the healthy and deteriorating aspen clones shown in figures 1 and 2 are given in table 1. Because of the nature of the criteria used in selecting healthy and deteriorating clones, the density of living stems was significantly lower and relative mortality higher in deteriorating clones than in healthy clones. The stems in the deteriorating clones were significantly younger in age and thus smaller in both diameter and height than those in healthy clones. They also showed less natural pruning and poorer form as indicated by their high crown ratios and low relative bole lengths. Site index, as determined from Jones' (1967) site index curves, was significantly higher in healthy clones than in deteriorating clones.

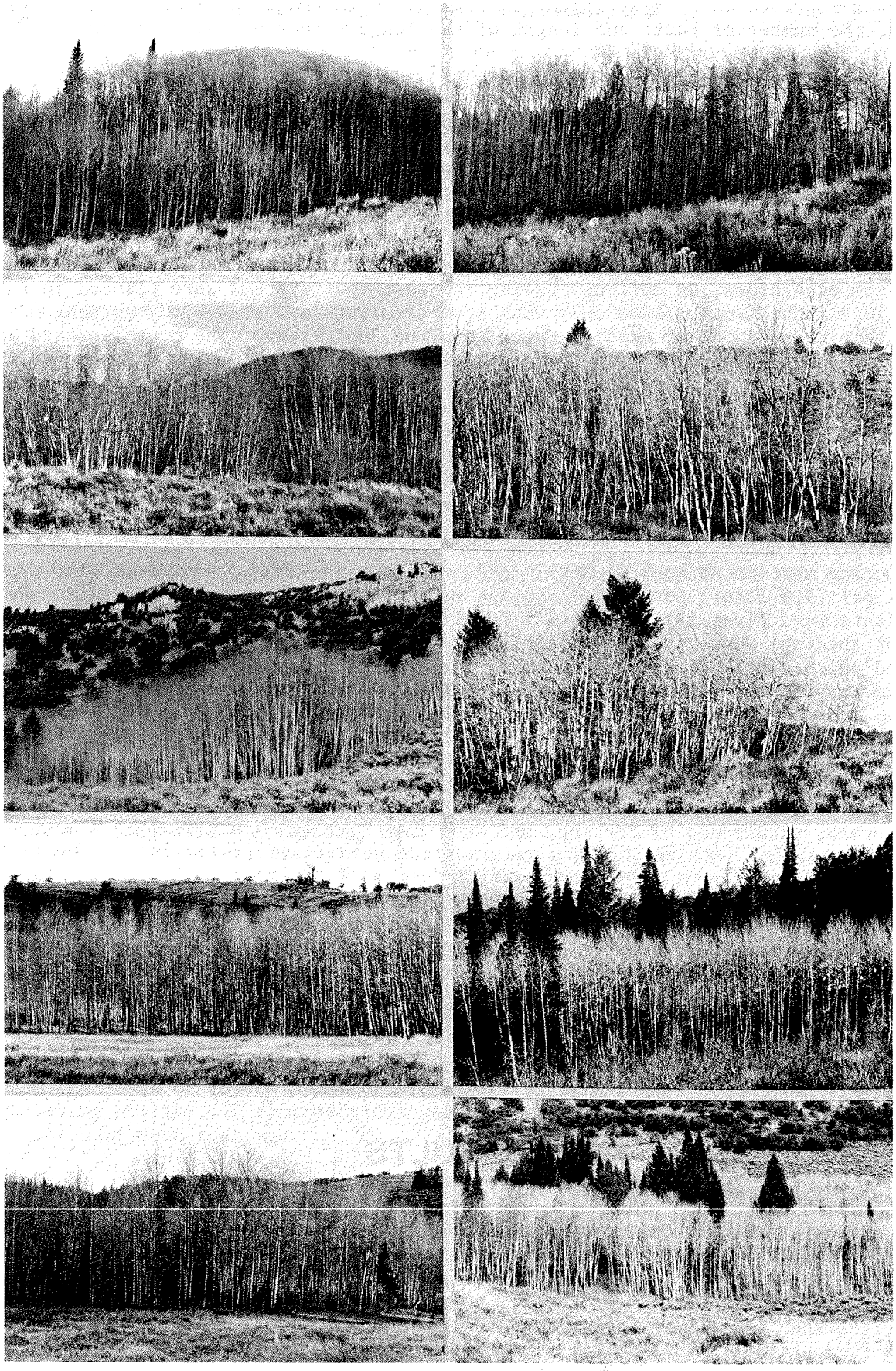

Figure 1.--Healthy aspen clones used in this study. November 1976.

Figure 2.--Deteriorating aspen clones used in this study. November 1976.

Table 1.--*Description of the stands (stems with a d.b.h. 0.78 inch [2 cm] and larger) of healthy and deteriorating aspen clones. The measurements shown are mean values determined by sampling*

Clone	Stem age	d.b.h.[1]	Total height	Crown ratio[2]	Relative bole length[3]	Living stems per ha	Dead stems per ha	Dead stems % of total	Basal area	Site index[4]
	Years	*cm*	*m*	*Percent*	*Class*				*m^2/ha*	*m*
					Healthy Clones					
1	128	16.6	16.0	25	3.1	1,600	25	1.5	38.6	11.9
2	92	13.5	17.9	36	3.4	3,150	400	11.3	54.3	16.2
3	86	8.4	12.5	35	2.6	5,850	600	9.3	34.4	11.6
4	88	17.7	17.1	33	2.9	2,567	200	7.2	71.1	15.9
5	98	14.2	19.2	35	2.7	1,450	100	6.5	29.3	18.0
6	99	13.5	14.5	23	2.5	1,900	633	25.0	29.5	12.5
7	99	12.6	12.9	23	3.5	2,150	850	28.3	28.8	11.6
8	58	10.3	11.0	35	3.9	3,200	500	13.5	35.2	12.8
9	117	12.3	16.0	29	3.6	2,950	300	9.5	45.4	12.5
10	118	10.7	11.2	36	3.9	2,533	267	9.5	23.8	8.8
Average	98.3	12.98	14.83	31.0	3.21	2,735	388	12.16	39.04	13.18
					Deteriorating Clones					
1	77	6.5	12.0	48	3.6	2,550	475	15.7	10.5	11.6
2	83	8.4	8.4	61	3.9	367	50	11.9	2.6	8.2
3	67	7.6	10.6	51	3.7	688	375	35.3	4.2	11.6
4	53	8.7	8.6	53	3.9	1,267	200	13.6	8.2	10.7
5	58	8.3	6.5	55	3.8	733	116	13.7	4.6	7.0
6	54	6.0	7.5	52	3.9	2,650	1,250	32.1	8.2	9.1
7	49	4.5	7.7	49	3.9	2,433	2,200	47.5	4.1	9.5
8	80	7.0	9.4	53	3.9	786	286	26.7	3.5	9.5
9	60	7.2	8.3	46	3.3	757	143	15.9	3.7	9.1
10	79	6.8	9.7	46	3.9	204	250	55.1	0.8	9.5
Average	66.0	7.10	8.87	51.4	3.78	1,244	535	26.75	5.04	9.58
					Significant Differences Between Groups[5]					
	**	**	**	**	**	**	N.S.	*	**	**

[1]Diameter at breast height, 4.5 ft (1.37 m).

[2]Proportion of the bole that supports living foliage.

[3]Length of the longest straight section of a tree as a percent of the length that would be expected in the absence of deformities. Four classes: 1. 90 to 100 percent; 2. 75 to 90 percent; 3. 50 to 75 percent; and 4. <50 percent.

[4]Determined from Jones' (1967) site index curves-base age 80 years.

[5]* = Significant at 0.05 level, ** = significant at 0.01 level, N.S. = nonsignificant.

Although the mean density of sucker regeneration in healthy clones was twice that in deteriorating clones (table 2), the differences were not statistically significant. This was due to the high variation in numbers of suckers among healthy clones. It ranged from less than 400 suckers per acre (1 000/ha) to over 8,500 per acre (21 000/ha). Sucker regeneration was also expressed in numbers of clumps because only one sucker in a clump is likely to grow into a mature stem.

Table 2.--*Density of sucker regeneration (stems having a d.b.h. smaller than 0.78 inch [2 cm]) in healthy and deteriorating clones expressed in number of individual suckers and in number of sucker clumps*

	Healthy clones			Deteriorating clones		
Clone	Suckers per ha	Clumps[1] per ha	Frequency	Suckers per ha	Clumps per ha	Frequency
			Percent			*Percent*
1	21,760	8,820	29	6,520	5,220	22
2	19,200	13,600	40	6,670	4,100	21
3	17,220	12,220	42	7,830	5,650	24
4	4,410	3,240	16	2,900	1,610	8
5	4,410	3,820	18	670	670	3
6	6,670	5,000	17	1,875	1,875	9
7	<625	625	1	3,580	3,280	13
8	3,700	2,220	11	3,200	2,400	12
9	<770	770	1	1,765	1,765	9
10	8,000	6,670	23	1,600	1,600	8
Average	8,676	5,698	19.8	3,661	2,817	12.9

[1]Maximum area covered by a clump of suckers did not exceed a circular area 7.87 inches (20 cm) in diameter.

All three root suckering tests (September 1974, July 1975, and May 1976) performed with excised roots gave the same results (table 3): no significant difference between healthy and deteriorating clones in sucker production or growth. Analysis of variance showed that both measures of suckering capacity were, however, significantly (1 percent level) affected by clone and date and that there was a significant clone-date interaction. Mean age of roots (0.39 to 0.78 inch [1 to 2 cm] diameter) from healthy and deteriorating clones used in the suckering tests was similar. Within each group of aspen clones there was considerable variation in root ages which showed no relationship to suckering capacity.

Rooting ability of sucker cuttings (table 4) probably has no relationship to the capacity of aspen clones to regenerate under natural conditions, but it may be a good measure of the physiological condition of the clones. There were significant differences among clones in rooting percentages, number of roots, and root length, but, none of these characteristics showed significantly large differences when the means of healthy and deteriorating clones were compared.

Survival percentages and stem and crown characteristics of the aspen ramets are given in table 5. Although significant clonal differences were found for these variables, there were no significant differences between the means of healthy and deteriorating clones.

Table 3.--*Mean suckering ability of root segments (3.94 inches [10 cm] x 0.39 to 0.78 inch [1 to 2 cm]) from healthy and deteroirating aspen clones and mean age of roots used. Suckers were counted after a 42-day propagation period.*

Clone	Root age	Suckers per segment				Height of tallest sucker			
		5/76	7/75	9/74	Average	5/76	7/75	9/74	Average
	Years					*mm*			
				Healthy Clones					
1	20.4	10.5	6.0	9.2	8.57	29	26	31	28.7
2	19.2	4.9	2.7	6.0	4.53	39	33	34	35.3
3	22.2	5.9	6.1	4.5	5.50	37	30	33	33.3
4	21.4	2.4	5.5	5.0	4.30	46	41	34	40.3
5	13.5	4.4	10.7	3.4	6.17	35	30	24	29.7
6	17.6	7.3	8.7	7.3	7.77	47	42	44	44.3
7	20.8	6.9	7.5	7.1	7.17	38	32	44	38.0
8	22.8	14.0	21.4	13.3	16.23	28	26	32	28.7
9	28.0	6.7	12.7	21.4	13.60	36	31	37	34.7
10	23.0	4.5	3.6	16.5	8.20	32	30	35	32.3
Average	20.89	6.75	8.49	9.37	8.20	36.7	32.1	34.8	34.5
				Deteriorating Clones					
1	18.4	5.9	3.4	5.0	4.77	29	21	30	26.7
2	22.8	8.4	8.2	9.3	8.63	39	27	42	36.0
3	18.6	2.2	2.1	4.1	2.80	37	22	30	29.7
4	17.8	6.5	15.3	9.5	10.43	46	27	44	39.0
5	21.2	5.0	5.6	3.9	4.83	35	36	49	40.0
6	18.2	11.1	15.4	21.2	15.90	47	30	36	37.7
7	20.1	7.9	8.3	14.6	10.27	38	23	32	31.0
8	16.9	6.2	9.8	4.6	6.87	28	30	44	34.0
9	24.2	6.0	6.0	6.5	6.17	36	29	35	33.3
10	25.1	6.1	3.1	4.6	4.60	32	30	35	32.3
Average	20.33	6.53	7.72	8.33	7.53	36.7	27.5	37.7	34.0

Table 4.--*Mean rooting ability of sucker cuttings from healthy and deteriorating aspen clones. Suckers originated from roots collected in September 1974. Cuttings were in the rooting media for 3 weeks*

Clone	Healthy clones			Deteriorating clones		
	Percentage of cuttings rooting	Roots per rooted cutting	Length of longest root	Percentage of cuttings rooting	Roots per rooted cutting	Length of longest root
			mm			*mm*
1	28	1.9	27	33	2.2	38
2	42	1.8	29	72	2.3	50
3	55	2.3	40	67	2.3	37
4	68	1.9	38	30	1.6	20
5	60	1.9	34	25	2.1	48
6	35	2.0	41	73	3.6	55
7	75	2.2	52	85	3.2	57
8	67	2.3	34	57	2.4	35
9	73	1.8	44	35	1.2	36
10	48	2.4	31	12	1.3	12
Average	55.1	2.05	37.0	48.9	2.22	38.8

Table 5.--*Survival percentages and growth characteristics of rooted sucker cuttings from healthy and deteriorating aspen clones after 2 years growth in containers. Thirty cuttings of each clone were planted*

Clone	Survival	Total 2-year growth	Laterals		Forking	Stem form[1]
			Number	Average length		
	Percent	*cm*			*Percent*	
			Healthy Clones			
1	73	114	6.2	23.8	36	3.2
2	93	80	4.6	14.8	0	3.0
3	73	113	2.5	17.3	59	2.1
4	93	80	5.5	7.8	11	2.2
5	87	100	5.4	14.3	8	2.8
6	73	77	5.4	12.3	32	2.6
7	83	112	7.1	14.6	8	2.8
8	73	96	2.3	18.6	27	2.6
9	27	114	6.2	23.5	14	2.5
10	93	69	6.7	10.1	18	2.5
Average	76.8	95.5	5.19	15.51	21.3	2.63
			Deteriorating Clones			
1	90	94	4.8	18.2	15	2.7
2	43	61	4.5	24.2	31	2.2
3	40	84	4.8	12.3	8	2.9
4	93	102	3.8	17.9	29	2.8
5	100	88	10.4	14.0	10	2.3
6	80	99	6.4	21.6	17	2.3
7	93	113	7.6	23.0	14	2.6
8	67	119	3.5	19.9	25	2.9
9	47	62	4.0	9.4	29	2.4
10	40	83	4.3	14.4	17	3.1
Average	69.3	90.5	5.41	18.39	19.5	2.62

[1]Scored: 1 (straight) to 5 (very crooked).

The mean values of environmental variables associated with healthy and deteriorating clones are shown in table 6. Only two variables differed significantly between the two groups. The mean phosphorus concentration and the mean percentage of silt of the upper soil layer were higher in the healthy clones than in the deteriorating clones. Percentage of silt is one of the best estimates of available water-holding capacity (Hill 1959); so during the growing season soil water conditions are more likely to be better in healthy than they are in deteriorating clones. Although the concentration of the other soil nutrients (sodium, potassium, calcium, magnesium, and nitrogen) showed relatively small differences between the two types of clones, it was interesting that in all instances the levels were higher in deteriorating clones.

When the soil cores were taken in each clone, presence of rocky horizons or conglomerate layers was noted. They occurred at less than 19.7 inches (50 cm) from the soil surface in five deteriorating clones (1, 3, 8, 9, and 10) and in one healthy clone (1). This indicates that deteriorating clones occur with greater frequency on shallow soils than healthy clones. Shallow soil reduced available water-holding capacity of the site.

Table 6.--*Environmental characteristics of sites occupied by healthy and deteriorating aspen clones. Averages are based on 10 clones in each group. Soil properties are shown for upper (U, 0 to 7.9 inches [0 to 20 cm]) and lower (L, 31.5 to 39.4 inches [80 to 100 cm]) soil depths sampled*

Characteristics		Healthy clones	Deteriorating clones	Significance of difference[1]
Elevation		2,224 ± 130	2,197 ± 109	N.S.
Aspect		0.966 ± 0.726	0.965 ± 0.706	N.S.
Slope (%)		18.0 ± 12.9	14.7 ± 8.3	N.S.
Exposure		2.8 ± 0.9	2.5 ± 0.8	N.S.
Slope position		2.6 ± 1.7	3.2 ± 0.6	N.S.
pH	U	6.58 ± 0.28	6.57 ± 0.21	N.S.
	L	6.63 ± 0.66	6.33 ± 0.46	N.S.
Cation exchange capacity (meq/100g)	U	30.95 ± 6.20	32.94 ± 4.02	N.S.
	L	21.76 ± 6.97	26.57 ± 5.81	N.S.
Sodium (meq/100 g)	U	0.22 ± 0.04	0.33 ± 0.15	N.S.
	L	0.23 ± 0.05	0.40 ± 0.26	N.S.
Potassium (meq/100 g)	U	1.38 ± 0.46	1.58 ± 0.31	N.S.
	L	0.68 ± 0.28	0.71 ± 0.32	N.S.
Calcium (meq/100 g)	U	27.86 ± 10.38	30.51 ± 6.87	N.S.
	L	19.81 ± 9.30	25.90 ± 14.15	N.S.
Magnesium (meq/100 g)	U	3.57 ± 1.32	4.69 ± 1.13	N.S.
	L	3.46 ± 2.39	3.85 ± 1.16	N.S.
Phosphorus (ppm)	U	56.0 ± 22.4	35.8 ± 14.50	*
	L	20.1 ± 13.1	10.4 ± 11.10	N.S.
Organic carbon (%)	U	5.63 ± 1.38	5.38 ± 1.18	N.S.
	L	0.89 ± 0.38	1.30 ± 0.59	N.S.
Total nitrogen (%)	U	0.368 ± 0.078	0.411 ± 0.051	N.S.
	L	0.088 ± 0.029	0.118 ± 0.039	N.S.
Silt (%)	U	45.0 ± 7.7	37.2 ± 6.4	*
	L	40.0 ± 6.8	35.0 ± 9.9	N.S.
Sand (%)	U	16.3 ± 5.9	19.8 ± 5.7	N.S
	L	18.7 ± 10.2	19.4 ± 11.7	N.S.
Clay (%)	U	38.7 ± 6.9	43.0 ± 6.0	N.S.
	L	41.3 ± 7.8	45.6 ± 6.4	N.S.

[1]N.S. = nonsignificant; * = significant at 0.05 level.

DISCUSSION

There were significant differences between stand and individual tree characteristics of healthy and deteriorating clones (table 1). Propagated under uniform conditions, however, 2-year-old ramets of healthy and deteriorating clones failed to show any significant differences in their morphological characteristics (table 5). Suckering and rooting tests also indicated that there were no differences between the two categories of clones in their capacities for vegetative propagation (tables 3 and 4). The root suckering tests corroborated earlier findings by Schier (1975).

Although the young ramets gave no indication of a relationship between aspen longevity and morphological characteristics, differences between healthy and deteriorating clones may develop when the trees grow in size and complexity in a common garden. We may, however, be wrong in assuming that deteriorating clones have distinctive morphological characteristics. Aspen longevity may depend on physiological characteristics or well established clonal growth habits that enable a clone to survive during hot, dry summers or to increase its resistance to insects and disease. If this were the case, then a common garden where growing conditions are optimum would be a poor place to measure the ability of a clone to perpetuate itself. Also, it would be difficult to evaluate the various strategies that effect aspen survival if these are not expressed until the ramets of a clone become mature.

Another hypothesis that may have to be reevaluated is that the ratty condition of deteriorating clones, expressed by branchy, crooked stems, is inherent. These phenotypic characteristics may have been induced by stand conditions. In the Lake States, aspen deterioration is rapid and in as few as 6 years more than half of the trees in a well-stocked stand may have died (Graham and others 1963). These residual trees have straight, clear boles because the stands were dense while they were growing. In Utah clones, deterioration may take place more slowly, occurring over a number of generations of ramets. With time, stem density is slowly reduced as regeneration fails. Poor regeneration is a consequence of root dieback and the maintenance of apical dominance by residual stems (Schier 1975). Trees growing under these open conditions generally have large crowns and poor form.

The site indices of the clones indicated that the healthy clones were growing on better sites than the deteriorating clones. Although there was some evidence that insufficient soil moisture might be a factor contributing to the reduced longevity of aspen clones, this evidence was not strong. The absence of any meaningful relationship between height growth of clones and associated site factors indicates that the differences in site index were not due to the differences in site quality, but to inherent differences in growth rate or to open stand conditions. Zahner and Crawford (1965) describe the problem of using tree height to measure site productivity in a clonal species like aspen. In Michigan, they found considerable variation in the growth rates of big tooth aspen (*Populus grandidentata* Michx.) clones growing on the same site.

The concentration of phosphorus was lower in soils of deteriorating clones than in soils of healthy clones, but these levels were well above those necessary for good tree growth. The difference in phosphorus concentrations and other small, but consistent, differences in the chemical analysis of soils from the two kinds of clones may be caused by dissimilarities in their total vegetation. The understory vegetation in open deteriorating clones has a different species composition and represents a larger proportion of the total biomass than the understory of well-stocked healthy clones. This will affect nutrient cycling and, consequently, the chemical composition of the soils.

be evidence of relatively high mortality. Poor stocking is not sufficient evidence because some sites may support relatively few stems and low root density. Poor stocking may also be a genotypic characteristic. In other words, inherent characteristics of a clone, such as the ability to regenerate itself, the pattern of root development, and the ability of suckers to develop independent root systems, could all affect the population structure of clones.

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