TRANSLOCATION STUDIES IN THE SUBMERGED TISSUES OF AQUATIC VASCULAR PLANTS

by

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AN ABSTRACT

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In order to grow diversified crops on much of the land in the western United States it is necessary to supplant the moisture provided by nature in the form of rain, snow, etc., with additional water which reaches farm lands through established irrigation canal distribution systems. These systems frequently support heavy growths of vascular aquatic plants which prevent or slow down the passage of water. Since reducing the carrying capacity of a canal makes it necessary to deprive some potentially crop-producing land of the required water to bring the crop to a satisfactory harvest, it is imperative to keep the waterways open.

This thesis is a report of certain pertinent investigations which suggest improved and more effective field techniques to accomplish a solution of the problem at hand.

Broad- and narrow-leaved cattail, water sedge, true waterweed, American pondweed, horned pondweed, leafy pondweed, Richardson's pondweed, gigantic sage pondweed, and slender sago pondweed plants were transplanted from the field directly to containers with as little root disturbance as possible. Spraying of the submerged aquatic plant materials in the water drained tanks was performed with a 1-quart capacity model A, Sure Shot pneumatic sprayer.

Lethal effects of 2,4-D ester appeared to be transmitted through the immersed cattail leaf, past the waterline, and into the crown of the plant. No shoot regrowth developed in ester treated plants.

When broad-leaved cattail roots were immersed for 24 hours in 10 ppm of the salt and ester forms of 2,4-D, and the ester form of

2,4,5-T, effect of the passage of the systemic herbicides into the plants was evidenced by the fact that no shoot regrowth was in evidence 8 weeks following leaf harvest.

When aerial herbicidal treatments were made the following single or repeated 2,4-D applications were effective in obtaining complete, or nearly complete, eradication of the waterweeds growing in the soil bottom of the treated tanks.

Name of plant	Pounds per acre	Number of treatments	Percent eradication
Narrow-leaved cattail	25	1	100
Broad-leaved cattail	41	1	100
Water sedge	27	1	85
True waterweed	5	1	100
Leafy pondweed	5	1	100
American pondweed	10	1	95
Gigantic sago pondweed	20	2	95
Richardson's pondweed	12	2	98
Horned pondweed	11	2	100

A study was made of the changes in cattail root reserves in underground plant parts which are due to seasonal growth phenomena. Weekly measurements were made throughout the entire growing season in an attempt to correlate below-ground carbohydrate root reserves with easily observed above-ground phenomena.

Broad- and narrow-leaved cattail roots showed considerable variation in the amount of carbohydrates present during the growing season. Highest carbohydrate was present during the winter dormancy period and lowest carbohydrate was associated with production and maturation of male and female fruiting bodies. Root reserves are low from the time of the first appearance of the fruiting stalks until pollination has been completed.

In the narrow-leaved and broad-leaved cattail growth sites, not inundated by water, root reserves were at a minimum when the plants had attained a height of approximately 100-130 cm and 50-120 cm above the ground line respectively.

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INTRODUCTION

For the past several years, the number of acres of land placed under irrigation in the western United States has increased. This same land, without additional water to supplant that provided by nature in the form of rain, snow, etc., has been totally without, or of much less, value from the standpoint of growing crops. To provide this water, not only is it necessary for river waters to be impounded and irrigation canal distribution systems established, but also for the irrigation waterways to be free of obstructing plant growths which prevent or slow down the passage of water.

Reduction in carrying capacity of a canal can mean only one thing; i.e., some potentially crop-producing land will be deprived of the necessary water to bring the crop to a satisfactory harvest. Therefore, it is imperative to keep the waterways open.

Balcom (1), Crafts (5), and Speirs (33), have discussed the several methods used in the past in the attempt to keep the waterways open. Among these are chaining, draining, dredging, burning, biological control, and chemical control. None of these have been satisfactory or generally permanent because the roots, rhizomes, or other propagules of the treated aquatic vascular plants have not been killed.

Several chemicals, separately and in various combinations, have produced browning and defoliation of waterweed leaves, or a temporary kill of only the top portion of the plant in irrigation ditches but the viable rootstocks have remained as a source of new growth.

Thus, it is not only desirable to destroy vegetative growth present in an irrigation channel, but also to allow an absolute minimum of fruits or seeds, lateral or winter buds, or fragmentation propagules to remain behind for new infestation.

At the beginning of each growing season many vascular plants use the starch food reserves stored in their roots to build new plant tissue. This process continues until such a time as the chlorophyll-bearing tissue of the new plant can manufacture food in the quantities needed for the new growth. As plant growth slows up, the chlorophyll-bearing tissue in the new plant is able to catch up with, and then surpass, the immediate demands for food used in the manufacture of new tissue; this results, of course, in starch reserves being put back in the underground storage organs for use at a later date.

Chemical analyses, presented later, of the broad- and narrow-leaved cattail rootstocks show that carbohydrate is the principal form of food reserve storage. It seems probable that the other aquatic plants discussed in this paper store their food reserves in a like manner.

Evans, Mitchell and Heinen (7), Rasmussen (25), Smith, Hamner and Carlson (32), have shown that phenoxyacetic acid derivatives, in herbicidal concentrations, stimulate plant respiration, food digestion, and utilization of reserve food materials.

Freeland (12) observed that 2,4-D at concentrations of 30 and 100 ppm decreased the rate of photosynthesis in true waterweed (<u>Anacharis</u>

canadensis), with the higher concentration being more effective.

Mitchell and Brown (20) treated morning-glory (Ipomoea lacunosa) plants with 2,4-D in herbicidal concentrations and found a depletion of readily available carbohydrates within a 3-week period after treatment.

Hall and Hess (14) have suggested that the relatively high tolerance of submerged aquatics to 2,4-D is associated with their reduced vascular systems and resulting limited transport of phenoxyacetic acid derivatives. Draining water off of the plants before treatment would therefore appear essential for the most effective control of submerged species with 2,4-D.

So far as is known, Surber, Minarik and Ennis (34) are the only workers who have controlled normally submerged aquatic plants by first draining off the water and then spraying with systemic herbicides, the flaccid, rooted aquatic plants lying on the soil bottom. In this case, a pond supporting American pondweed (Potamogeton nodosus) was drained and bottom sprayed with 2,4-D dissolved in tributylphosphate at the rate of 10 pounds 2,4-D acid equivalent per acre. American pondweed shoots failed to reappear after this herbicidal treatment.

It will be shown that when broad- and narrow-leaved cattails (Typha latifolia and Typha angustifolia, respectively) and water sedge (Carex aquatilis) were treated with phenoxyacetic acid derivatives in herbicidal concentrations, a depletion of readily available carbohydrates occurred in the underground roots and rhizomes of these plants.

Plant regenerative power is at its lowest ebb when food reserves are low. Accordingly, application of any given herbicide, contact or systemic, at the time when food reserves are low should effect the most successful eradication or control with expenditure of minimum time, effort, and cost.

Because of recent widespread success of certain phenoxyacetic acid derivatives on landweeds, the effect of these compounds on obnoxious submerged aquatic weeds was believed to be worth investigating. To this end, translocation studies in the water-submerged tissues of aquatic vascular plants were made.

Since carbohydrates in the crown, rhizome, and root of the cattail plants appear to be equally readily available to the plant for new growth, the word "root" is used in this study to include that part of the underground tissue below the line from which fibrous roots emerge.

ANATOMY OF AQUATIC VASCULAR PLANTS

Structural changes in vascular hydrophytes which Eames and MacDaniels (6) considered as adaptations to aquatic environments are reduction of protecting, supporting, and conducting tissues and frequent provision for aeration the full length of the plant, i.e., leaf, stem, root, by the development of air chambers. Finely divided, terete leaves allow for increased contact between leaf surface and surrounding water. Absorption of gases and nutrients takes place directly from the water by stem and leaf. The epidermis commonly contains chloroplasts and may thus form a considerable part of the photosynthetic tissue, especially where the leaves are very thin.

In submerged tissues of hydrophytes, stomata are wanting. The floating leaves, however, e.g., in American pondweed (Potamogeton nodosus), have abundant stomata upon the upper surface. The greatest proportional reduction in the vascular tissue occurs in the xylem (see plates IX and X). In many forms the xylem consists of only a few elements, even in the stele and main vascular bundles. Less commonly, xylem elements are entirely lacking. In these cases there is usually a more or less well-defined xylem lacuna to mark the normal position of the xylem. Phloem tissues, on the other hand, are in most cases fairly well developed as compared with the xylem. They resemble the phloem tissue of reduced herbaceous plants generally, in that the sieve tubes are small as compared with those of woody plants. The endodermis is often weakly developed or may be entirely wanting.

It is important to note here that Mitchell and Brown (20) found that the stimulus resulting from 2,4-D application on bean plants was closely associated with translocation of organic food materials and that this stimulus occurred as a continual flow under conditions favorable for carbohydrate translocation and probably was confined to the living phloem or parenchyma cells.

Thimann (35), Weaver and DeRose (36) have shown that stomata are not important portals of entry for phenoxyacetic acid derivatives and that, when applied to the aerial portions of plants, the compound moves downward whenever translocation of synthesized materials occurs.

This downward movement of the phenoxyacetic acid stimulus through the living phloem or parenchyma cells is very important for, as pointed out, the phloem tissues of aquatic plants are in most cases well developed as compared with the xylem.

SEASONAL CARBOHYDRATE ROOT RESERVE TRENDS IN ROOTS AND RHIZOMES OF BROAD- AND NARROW-LEAVED CATTAILS

It will be pointed out further on in this study that it is possible for as many as 15-20 new plant entities to emerge from basally clipped cattail rootstocks. Apparently so long as lateral buds and adequate carbohydrate and other food reserves are retained in the underground parts, these clipped plants, other conditions being favorable, are capable of regenerating new plant growth.

It was desirable, accordingly, to study the changes in root reserves in these underground plant parts which were due to seasonal growth phenomena. Having established the period, or periods, of low root reserve it would thus be possible, by making herbicidal applications when root reserves are at a low ebb, to get maximum herbicidal effect with minimum time, effort, and cost.

As will be shown later, the majority of root reserves in broad- and narrow-leaved cattail were found to be in the form of carbohydrates.

Protein and crude fat determinations were made on broad- and narrow-leaved cattail root samples in accordance with methods suggested by Lepper (17), Loomis and Shull (18), and Woodman (37). Root samples of both species were taken from water inundated growing sites on April 10, 1950.

In this study of seasonal carbohydrate root reserve trends on broad- and narrow-leaved cattail roots and rhizomes (see plates IV and V), weekly measurements were made throughout the entire growing season in an attempt to correlate below-ground carbohydrate root reserves with easily observed above-ground phenomena.

Cattail carbohydrate root reserves were determined on the samples taken at weekly intervals and associated above-ground phenomena were recorded for the following situations:

1. Growing site inundated by water
    a. Fruiting broad-leaved cattail
    b. Nonfruiting broad-leaved cattail
    c. Mixture of fruiting and nonfruiting narrow-leaved cattail
2. Growing site not inundated by water (subirrigation)
    a. Mixture of fruiting and nonfruiting broad-leaved cattail
    b. Nonfruiting narrow-leaved cattail

Weekly notes on the above-ground phenomena for cattails in the above five categories were recorded as follows:

1. Date of collection
2. Appearance of fruiting bodies, pollination time, etc.
3. Weekly water temperatures approximately eight inches below lake surface
4. Height of plants above water surface, or ground line
5. Total length of plant shoots
6. Total length of seed stalk
7. Length of the female and male spikes
8. Width of female spike

9. Width of leaf

Weekly laboratory data were recorded as follows:

1. Shoot and root fresh weight

2. Shoot and root oven-dry weight

3. Percent dry matter in shoots and roots

4. Percentage readily hydrolizable carbohydrate in oven-dry roots

After field linear measurements had been made on about seven specimens from each grouping as listed earlier, the cattails were dug, brought into the laboratory, the soil washed off the roots, and the remaining laboratory linear measurements made.

The roots were then separated from the shoots and cut up into approximately 1/2-inch lengths (line of separation determined by the point of emergence of fibrous roots). The shoots and roots were placed in separate paper sacks and weighed. The shoots and roots were then placed in separate six-inch cubical wire baskets and heated in a drying oven at 100° C for 30 minutes as suggested by Miller (19) to inactivate the enzymes present. The oven temperature was then lowered to 62° C and the plant material heated for 72 hours.

The oven-dried shoots and roots were transferred to separate paper sacks and reweighed. The shoots were then discarded and the roots were stored in paper sacks in a cool, dry place so that later chemical analyses could be made on the specimens collected at weekly intervals through the growing season.

Carbohydrate root reserve in broad- and narrow-leaved cattail samples was determined as follows:

Preparation of sample. The dried, stored roots were pulverized in a Quaker City mill so that approximately 99.8 percent passed a 14-mesh sieve.

Table 1 shows the sieve analyses on 10 of the grinds used. The pulverized sample was placed over a nest of the Tyler standard screens of the sizes indicated, placed in a Ward shaker, and shaken for a period of five minutes.

To insure a uniform sample being taken, all the ground sample passing the No. 16 sieve was thoroughly mixed with a spatula after which a three-gram sample was weighed on a torsion balance.

It was recognized that, in cattail roots, starch is accompanied by root reserves such as pentosans and various hemicelluloses that also yield reducing sugars upon hydrolysis.

The method of direct acid hydrolysis was relatively quick and easy of execution, and sufficiently accurate to give results comparable with published analyses.

TABLE 1

TYLER STANDARD SCREEN SIEVE ANALYSES ON REPRESENTATIVE PULVERIZED CATTAIL ROOTS SIEVED FOR 5 MINUTES IN A WARD SHAKER

Sieve Number		Total	16	30	50	100	200	Pan
Meshes to the Inch			14	28	48	100	200	
Sample Number		Total						
1	Grams	23.8	0.0	0.6	5.4	6.8	5.0	6.0
	Percent	100.00		2.52	22.69	28.57	21.01	25.21
2	Grams	29.7	0.0	0.3	5.3	8.1	7.0	9.0
	Percent	100.00		1.01	17.85	27.27	23.57	30.30
3	Grams	23.1	0.1	0.3	4.5	6.6	4.6	7.0
	Percent	99.99	0.43	1.30	19.48	28.57	19.91	30.30
4	Grams	19.6	0.0	0.2	2.9	8.0	3.7	4.8
	Percent	100.01		1.02	14.80	40.82	18.88	24.49
5	Grams	17.5	0.1	0.3	3.1	5.6	3.6	4.8
	Percent	99.99	0.57	1.71	17.71	32.00	20.57	27.43
6	Grams	17.2	0.1	0.2	3.5	4.8	3.9	4.7
	Percent	99.99	0.58	1.16	20.35	27.91	22.67	27.32
7	Grams	25.0	0.0	0.1	4.4	8.9	6.3	5.3
	Percent	100.00		0.40	17.60	35.60	25.20	21.20
8	Grams	34.5	0.0	0.1	5.2	8.4	8.1	12.7
	Percent	100.00		0.29	15.07	24.35	23.48	36.81
9	Grams	33.0	0.1	0.7	6.9	7.7	7.8	9.8
	Percent	100.00	0.30	2.12	20.91	23.33	23.64	29.70
10	Grams	39.2	0.0	0.6	6.4	10.0	8.2	14.0
	Percent	100.00		1.53	16.33	25.51	20.92	35.71
Average percent			0.19	1.31	18.28	29.39	21.99	28.85

Results of protein, crude fat, and carbohydrate determinations made on oven-dried residue of broad- and narrow-leaved cattail root samples, both taken from a water inundated growing site on April 10, 1950, are presented in Table 2.

TABLE 2

CRUDE FAT, PROTEIN, AND CARBOHYDRATE CONTENT OF CATTAIL ROOTS

Name of plant	Percentage Crude Fat[1]	Percentage Protein[2]	Percentage Carbohydrate[3]
Narrow-leaved cattail *Typha angustifolia* L.	0.5280	2.55	60.17
Broad-leaved cattail *Typha latifolia* L.	1.2933	6.73	54.40

1. Lepper (17), Woodman (37)
2. Lepper (17), Woodman (37)
3. Loomis and Shull (28), Schaffer and Hartmann (31), Woodman (37)

From this table it can be seen that relatively small quantities of crude fat and protein are present in broad- and narrow-leaved cattail rhizome and roots and that the root reserve is primarily in the form of carbohydrates.

Results from chemical analyses of cattail root and rhizome samples collected at weekly intervals throughout the growing season are presented in Tables 3-7. These data show the changes in carbohydrate materials (see plate V) in these underground plant parts which are due to seasonal growth phenomena.

Date of Collection

Weekly cattail root collections and growth measurements began

TABLE 3

FIELD CARBOHYDRATE ROOT RESERVE STUDY ON MIXTURE OF FRUITING AND NONFRUITING NARROW-LEAVED CATTAIL PLANTS DEVELOPING FROM GROWING SITE INUNDATED BY WATER

Specimen Number	Date	Lake Surface H_2O Temp °F	Height above H_2O Surface cm	Final Length cm				Final Width cm	
				Leaf	Seed Stalk	Female Spike	Male Spike	Female Spike	Leaf
1	3-20-50	45.8							
2	3-27-50	51.8							
3	4-3-50	53.1							
4	4-10-50	54.2	8.9	20.3					
5	4-17-50	52.2	10.5	27.9					
6	4-24-50	57.5	33.8	33.7					
7[a]	5-1-50	54.2	24.1	38.9					0.6
8	5-8-50	52.5	47.3	63.1					
9	5-15-50	66.0	68.9	76.3					0.7
10	5-22-50	76.5	106.7	93.8					0.6
11[b]	5-29-50	66.1	97.0	84.3					
12[c]	6-5-50	74.0	107.3	115.9					0.7
13	6-12-50	73.0	125.9	150.7	119.6	12.4	19.4	0.5	0.6
14[d]	6-19-50	75.0	107.6	130.2	128.0	10.9	11.6	0.6	0.5
15[e]	6-26-50	84.0	130.1	133.9	128.7	10.6	13.5	0.9	0.6
16[f]	7-3-50	82.5	130.5	148.2	141.5	10.6	14.9	0.9	0.6
17	7-10-50	80.5	142.5	142.4	134.4	10.9	14.9	1.2	0.6
18	7-17-50	71.5	160.4	151.1	133.1	11.7	11.3	1.6	0.7
19	7-24-50	70.0	163.2	178.3	152.9	13.7		1.7	0.8
20	7-31-50	72.5	149.5	157.6	123.9	10.9		1.7	0.7
21	8-7-50	78.5	163.3	168.4	152.0	13.3	10.8	1.8	0.8
22	8-14-50	79.5	172.3	188.6	152.7	12.7		1.7	0.7
23	8-21-50	66.3	177.3	205.8	162.5	14.4		1.8	0.8
24	8-28-50	53.0	180.7	197.9	164.1	16.5		1.8	0.8
25	9-5-50	76.5	184.2	191.9	172.4	17.4		1.8	0.8
26	9-11-50	57.0	178.9	206.8	169.0	17.1		1.7	0.9
27[g]	9-18-50	61.6	162.8	184.2	167.6	15.6		1.8	0.9
28	9-25-50	60.5	166.2	217.8	176.4	17.3		1.8	0.8
29	10-2-50	55.0	180.1	229.0	172.3	16.8		1.6	1.0
30	10-9-50	54.0	172.5	186.9	159.2	15.4		1.6	0.8

a Cattail tops frozen back 6 to 8 inches.
b Green cattail leaves knocked down to water surface by snow.
c Narrow-leaved fruiting bodies beginning to appear.
d Narrow-leaved cattail beginning pollination.
e Narrow-leaved cattail pollination 50 percent completed.
f Narrow-leaved cattail pollination completed. Female spike cinnamon brown.

Final Weight				Percent Dry Matter		Percent Carbohydrate	Specimen Number
Fresh g		Oven-Dry g				Oven-dry	
Shoots	Roots	Shoots	Roots	Shoots	Roots	Roots	
	524.6		110.8		21.1	58.53	1
15.2	690.1	1.9	180.3	12.5	26.1	63.33	2
3.7	543.2	0.5	144.7	13.5	26.6	65.77	3
16.2	178.8	1.7	149.3	10.5	22.0	60.17	4
62.6	450.1	5.6	128.4	9.0	28.5	65.13	5
177.2	840.3	15.6	199.0	8.8	23.7	64.73	6
142.6	678.5	15.4	157.7	10.8	23.2	63.47	7
331.2	858.0	29.5	191.9	8.9	22.4	66.03	8
505.7	803.4	52.4	179.6	10.4	22.4	66.90	9
645.2	991.9	86.8	245.0	13.5	24.7	59.03	10
244.7	292.3	32.5	56.1	13.3	19.2	60.90	11
301.4	244.0	52.2	45.0	17.3	18.4	42.97	12
529.1	396.3	117.6	62.4	22.2	15.7	41.77	13
503.1	536.4	78.0	94.8	15.5	17.7	59.27	14
480.4	573.4	109.3	108.3	22.7	18.8	56.23	15
500.0	354.5	85.8	43.2	17.2	12.2	46.00	16
577.4	504.3	130.6	79.3	22.6	15.7	49.03	17
486.3	404.4	92.1	61.4	18.9	15.2	43.93	18
768.3	734.7	132.4	89.5	17.2	12.2	44.90	19
485.8	516.8	108.8	85.3	22.4	16.5	53.30	20
560.4	418.3	151.8	72.5	27.1	17.3	57.03	21
530.7	401.9	146.5	71.9	27.6	17.9	58.17	22
576.3	535.1	143.7	85.3	24.9	15.9	58.80	23
484.0	302.0	134.6	62.3	27.8	20.6	63.33	24
513.8	473.8	143.1	98.7	27.8	20.8	64.03	24
523.8	291.4	126.7	51.8	24.2	17.8	61.50	26
611.6	382.2	165.9	76.5	27.1	20.0	59.90	27
364.4	391.5	92.5	80.3	25.4	20.5	67.23	28
365.7	335.9	78.5	59.8	21.5	17.8	61.50	29
322.8	211.8	82.6	51.2	25.6	24.2	64.10	30

g Considerable yellowing in cattails.

TABLE 4

FIELD CARBOHYDRATE ROOT RESERVE STUDY ON NONFRUITING NARROW-LEAVED CATTAIL PLANTS DEVELOPING FROM GROWING SITE NOT INUNDATED BY WATER

Specimen Number	Date	Lake Surface H_2O Temp °F	Height above Ground Surface cm	Final Length cm				Final Width cm	
				Leaf	Seed Stalk	Female Spike	Male Spike	Female Spike	Leaf
1	3-20-50	45.8							
2	3-27-50	51.8							
3	4-3-50	53.1							
4	4-10-50	54.2							
5	4-17-50	52.2							
6	4-24-50	57.5		4.7					
7[a]	5-1-50	54.2							
8	5-8-50	52.5							
9	5-15-50	66.0							
10	5-22-50	76.5	23.9	23.3					0.4
11[b]	5-29-50	66.1	28.8	31.9					
12	6-5-50	74.0	35.0	42.8					0.6
13	6-12-50	73.0	54.4	56.1					0.5
14	6-19-50	75.0	67.9	72.6					0.7
15	6-26-50	84.0	87.9	86.3					0.7
16	7-3-50	82.5	101.7	105.6					0.7
17	7-10-50	80.5	120.3	121.8					0.8
18	7-17-50	71.5	126.4	124.5					0.9
19	7-24-50	70.0	126.4	111.5					0.7
20	7-31-50	72.5	136.4	135.0					0.8
21	8-7-50	78.5	141.5	140.4					0.8
22	8-14-50	79.5	142.7	142.9					0.8
23	8-21-50	66.3	136.3	140.9					0.8
24	8-28-50	53.0	148.5	146.7					0.7
25	9-5-50	76.5	140.1	152.8					0.8
26	9-11-50	57.0	138.5	118.6					0.7
27[c]	9-18-50	61.6	138.3	150.7					0.9
28	9-25-50	60.5	137.3	111.1					0.7
29	10-2-50	55.0	142.2	130.9					0.8
30	10-9-50	54.0	123.4	116.1					0.7

a Cattail tops frozen back 6 to 8 inches.
b Green cattail leaves knocked down to water surface by snow.
c Considerable yellowing in cattails.

Final Weight				Percent Dry Matter		Percent Carbohydrate	Specimen Number
Fresh g		Oven-Dry g				Oven-dry	
Shoots	Roots	Shoots	Roots	Shoots	Roots	Roots	
	345.5		91.7		26.5	62.27	1
	247.9		65.0		26.2	57.40	2
	213.0		57.4		27.0	61.37	3
	156.4		42.6		27.2	59.53	4
	86.4		19.6		22.7	51.70	5
	129.8		28.6		22.0	53.23	6
	121.7		25.5		21.0	48.03	7
	123.8		20.4		16.5	44.40	8
	190.7		37.8		19.8	49.53	9
106.5	479.0	15.8	112.0	14.8	23.4	57.80	10
169.7	769.0	22.5	162.9	13.3	21.2	56.67	11
87.8	464.7	14.0	105.5	15.9	22.7	51.77	12
215.0	606.0	29.6	128.6	13.8	21.2	53.43	13
182.4	309.4	24.9	52.8	13.7	17.1	49.93	14
285.3	223.1	60.3	51.3	21.1	23.0	57.97	15
210.4	111.2	39.6	15.4	18.8	13.8	43.63	16
405.3	256.0	85.7	44.8	21.1	17.5	46.47	17
408.8	207.8	72.4	30.4	17.7	14.6	43.00	18
484.4	881.5	100.0	138.6	20.6	15.7	45.03	19
340.2	204.0	89.1	38.3	26.2	18.8	54.80	20
272.0	168.9	78.9	32.8	29.0	19.4	55.77	21
316.7	160.6	82.6	26.3	26.1	16.4	49.20	22
293.1	230.6	80.0	50.8	30.7	22.0	54.97	23
241.8	279.3	74.5	63.7	30.8	22.8	61.53	24
190.9	179.5	62.6	46.9	32.8	26.1	60.03	25
194.3	280.6	61.2	66.8	31.5	23.8	59.90	26
277.8	191.0	117.0	54.9	42.1	28.7	63.03	27
179.2	223.4	59.4	65.7	33.1	29.4	61.10	28
312.6	259.3	92.1	64.4	29.5	24.8	61.23	29
117.3	160.9	52.8	39.7	45.0	24.7	62.20	30

TABLE 5

FIELD CARBOHYDRATE ROOT RESERVE STUDY ON NONFRUITING BROAD-LEAVED CATTAIL PLANTS DEVELOPING FROM GROWING SITE INUNDATED BY WATER

Specimen Number	Date	Lake Surface H_2O Temp °F	Height above H_2O Surface cm	Final Length cm				Final Width cm	
				Leaf	Seed Stalk	Female Spike	Male Spike	Female Spike	Leaf
1	3-20-50	45.8	10.2	20.8					1.0
2	3-27-50	51.8	12.7	28.3					1.0
3	4-3-50	53.1	14.0	29.7					
4	4-10-50	54.2	27.3	28.2					
5	4-17-50	52.2	24.8	62.7					
6	4-24-50	57.5	49.4	69.5					
7[a]	5-1-50	54.2	53.4	82.7					1.5
8	5-8-50	52.5	78.9	103.3					
9	5-15-50	66.0	100.7	130.1					1.5
10	5-22-50	76.5	137.2	145.0					1.6
11[b]	5-29-50	66.1	129.2	147.3					
12	6-5-50	74.0	141.1	152.5					1.5
13	6-12-50	73.0	134.3	156.2					1.7
14	6-19-50	75.0	135.7	163.8					1.6
15	6-26-50	84.0	178.5	188.9					1.5
16	7-3-50	82.5	180.7	209.5					1.4
17	7-10-50	80.5	177.0	185.3					1.4
18[c]	7-17-50	71.5	173.6	191.1					1.4
19	7-24-50	70.0	176.8	210.3					1.5
20	7-31-50	72.5	182.9	180.8					1.3
21	8-7-50	78.5	186.4	213.1					1.5
22	8-14-50	79.5	190.6	221.7					1.4
23	8-21-50	66.3	208.6	240.9					1.5
24	8-28-50	53.0	192.8	229.0					1.5
25	9-5-50	76.5	207.4	219.1					1.4
26	9-11-50	57.0	199.6	247.2					1.5
27[d]	9-18-50	61.6	195.8	243.5					1.5
28	9-25-50	60.5	196.5	232.6					1.4
29	10-2-50	55.0	169.4	235.0					1.4
30	10-9-50	54.0	158.0	208.4					1.2

a. Cattail tops frozen back 6 to 8 inches
b Green cattail leaves knocked down to water surface by snow.
c Broad-leaved cattail vegetative tips browned.
d Considerable yellowing in cattails.

Final Weight				Percent Dry Matter		Percent Carbohydrate	Specimen Number
Fresh g		Oven-Dry g				Oven-dry	
Shoots	Roots	Shoots	Roots	Shoots	Roots	Roots	
128.8	174.3	8.1	28.6	6.3	16.4	55.10	1
220.9	440.3	15.2	62.3	6.9	14.2	51.27	2
46.8	362.9	3.9	55.1	8.3	15.2	52.83	3
165.2	555.6	13.1	90.7	7.9	16.3	54.40	4
106.2	217.8	9.1	29.3	8.6	13.5	50.77	5
553.6	299.2	38.8	45.2	7.0	15.1	39.77	6
564.9	652.0	47.5	93.9	8.4	14.4	48.53	7
673.3	410.1	47.1	39.8	7.0	9.7	38.33	8
1325.7	559.4	107.8	47.7	8.2	8.5	28.60	9
1067.2	918.3	102.2	92.9	9.6	10.1	29.70	10
1019.1	618.9	100.0	48.9	9.8	7.9	25.20	11
946.7	666.3	114.6	64.4	12.1	9.7	29.77	12
660.7	451.8	98.0	50.5	14.8	11.2	22.10	13
1195.9	508.0	128.8	36.3	10.8	7.1	27.27	14
835.6	683.6	140.9	64.8	16.8	9.5	31.70	15
700.8	858.8	105.3	70.9	15.0	8.2	32.07	16
868.0	678.6	174.9	64.3	20.1	9.5	33.67	17
783.4	1007.3	129.6	99.3	16.5	9.9	37.17	18
806.0	1208.9	133.5	127.7	16.6	10.6	40.50	19
516.9	755.6	99.7	92.9	19.3	12.3	40.83	20
602.8	751.6	152.6	97.8	25.3	13.0	49.37	21
646.4	892.2	135.0	139.8	20.9	15.7	59.90	22
575.8	968.0	133.8	173.5	23.2	17.9	62.67	23
410.3	610.7	91.9	108.6	22.4	17.8	63.20	24
349.6	703.8	89.6	141.8	25.7	20.1	65.00	25
535.2	621.3	126.5	133.5	23.6	21.5	65.90	26
487.6	596.9	121.7	150.1	25.0	25.1	69.53	27
446.5	720.1	122.8	173.7	27.5	24.1	68.73	28
467.7	405.1	107.0	96.8	22.9	23.9	69.83	29
356.9	533.6	100.0	135.2	28.0	25.3	72.00	30

TABLE 6

FIELD CARBOHYDRATE ROOT RESERVE STUDY ON FRUITING BROAD-LEAVED CATTAIL PLANTS DEVELOPING FROM GROWING SITE INUNDATED BY WATER

Specimen Number	Date	Lake Surface H_2O Temp °F	Height above H_2O Surface cm	Final Length cm				Final Width cm	
				Leaf	Seed Stalk	Female Spike	Male Spike	Female Spike	Leaf
1	3-20-50	45.8	10.2	21.1					1.0
2	3-27-50	51.8	12.7	32.2					1.2
3	4-3-50	53.1	14.0	19.3					
4	4-10-50	54.2	27.3	39.1					
5	4-17-50	52.2	32.7	35.9					
6	4-24-50	57.5	56.9	80.7					
7[a]	5-1-50	54.2	58.0	74.2					
8	5-8-50	52.5	91.0	113.0					
9	5-15-50	66.0	106.0	120.5					1.5
10	5-22-50	76.5	137.2	141.6					1.5
11[b]	5-29-50	66.1	122.3	158.9					
12[c]	6-5-50	74.0	130.7	174.1					1.7
13	6-12-50	73.0	145.9	161.7	131.6	14.7	13.6	0.9	1.5
14[d]	6-19-50	75.0	141.1	160.1	144.2	9.4	17.8	1.0	1.5
15[e]	6-26-50	84.0	138.4	176.7	164.4	17.1	16.2	1.6	1.6
16[f]	7-3-50	84.5	140.8	166.5	154.9	14.4	17.0	2.0	1.6
17	7-10-50	80.5	155.1	179.2	175.2	11.5	11.3	1.8	1.6
18[g]	7-17-50	71.5	165.9	186.5	178.1	13.8	11.2	2.2	1.5
19	7-24-50	70.0	148.7	158.6	153.1	12.7		2.6	1.4
20	7-31-50	72.5	154.0	173.1	170.1	12.5	9.7	2.8	1.4
21	8-7-50	78.5	169.4	191.8	185.4	14.0	10.8	2.8	1.5
22	8-14-50	79.5	166.4	198.8	189.7	13.5		2.6	1.5
23	8-21-50	66.3	170.8	197.9	188.3	12.7		2.7	1.6
24	8-28-50	53.0	167.9	193.7	182.5	12.5		2.7	1.4
25	9-5-50	76.5	174.4	205.9	186.6	13.7		2.8	1.6
26	9-11-50	57.0	159.6	213.4	196.8	14.6		2.8	1.6
27[h]	9-18-50	61.6	155.7	201.6	194.2	13.9		2.8	1.6
28	9-25-50	60.5	164.4	210.2	202.7	14.2		2.7	1.6
29	10-2-50	55.0	166.9	207.2	198.6	14.3		2.7	1.4
30	10-9-50	54.0	155.2	201.6	196.1	14.1		2.6	1.4

a Cattail tops frozen back 6 to 8 inches.
b Green cattail leaves knocked down to water surface by snow.
c Broad-leaved cattail fruiting bodies beginning to appear.
d Broad-leaved cattail pollinating heavily.
e Broad-leaved cattail pollination 90 percent completed.
f Broad-leaved cattail pollination completed. Female spike black brown.
g Broad-leaved cattail vegetative tips browned.

Final Weight: Fresh g: Shoots	Final Weight: Fresh g: Roots	Final Weight: Oven-Dry g: Shoots	Final Weight: Oven-Dry g: Roots	Percent Dry Matter: Shoots	Percent Dry Matter: Roots	Percent Carbo-hydrate: Oven-dry: Roots	Specimen Number
131.7	230.7	8.5	38.6	6.5	16.7	57.03	1
345.3	425.6	23.7	64.0	6.9	15.0	51.70	2
19.4	287.3	1.9	43.8	9.8	15.2	52.13	3
149.4	453.3	10.7	69.8	7.2	15.4	48.40	4
86.9	316.8	6.5	44.4	7.5	14.0	50.70	5
427.3	402.7	32.6	52.8	7.6	13.1	46.60	6
713.4	1166.3	49.3	177.1	6.9	15.2	46.47	7
790.0	528.3	55.8	55.3	7.1	10.5	40.93	8
1064.2	911.0	82.5	97.0	7.8	10.7	40.37	9
915.4	568.8	96.3	57.0	10.5	10.0	32.40	10
1126.4	835.9	111.6	69.6	9.9	8.3	24.80	11
833.4	738.0	94.2	65.0	11.3	8.8	25.13	12
959.5	309.7	154.1	30.6	16.0	9.9	20.50	13
1229.3	545.8	133.1	41.0	10.8	7.5	21.27	14
1084.5	790.3	177.2	75.4	16.3	9.5	27.03	15
1000.2	475.4	138.5	36.5	13.8	7.7	24.90	16
973.3	277.6	183.6	27.3	18.8	9.8	30.40	17
1234.3	440.2	234.9	40.5	31.0	9.2	33.50	18
935.9	460.6	192.7	53.3	20.6	11.6	34.03	19
1083.9	600.3	249.3	22.3	23.0	12.0	30.60	20
732.7	386.7	204.1	45.9	27.9	11.9	33.53	21
715.7	342.0	152.9	32.5	21.4	9.6	32.17	22
1048.6	376.8	273.6	54.3	26.1	14.4	46.10	23
685.1	320.5	178.2	42.8	26.0	13.4	49.30	24
755.9	436.3	189.4	74.6	25.0	17.1	54.47	25
857.2	360.5	218.3	46.7	25.5	13.0	44.07	26
756.1	461.5	207.2	79.8	27.4	17.3	52.57	27
698.9	594.1	218.2	96.0	31.2	16.2	54.57	28
776.1	509.5	246.6	103.5	31.8	20.3	61.03	29
767.3	393.9	258.3	67.9	33.7	17.2	56.40	30

h Considerable yellowing in cattails.

TABLE 7

FIELD CARBOHYDRATE ROOT RESERVE STUDY ON MIXTURE OF FRUITING AND NONFRUITING BROAD-LEAVED CATTAIL PLANTS DEVELOPING FROM GROWING SITE NOT INUNDATED BY WATER

Specimen Number	Date	Lake Surface H_2O Temp ^oF	Height above Ground Surface cm	Final Length cm: Leaf	Final Length cm: Seed Stalk	Final Length cm: Female Spike	Final Length cm: Male Spike	Final Width cm: Female Spike	Final Width cm: Leaf
1	3-20-50	45.8							
2	3-27-50	51.8							
3	4-3-50	53.1							
4	4-10-50	54.2	3.3						
5	4-17-50	52.2	37.7						
6	4-24-50	57.5	14.7	15.1					
7[a]	5-1-50	54.2	24.9	25.7					
8	5-8-50	52.5	42.9	51.4					
9	5-15-50	66.0	54.8	46.6					1.0
10	5-22-50	76.5	95.4	84.7					1.3
11[b]	5-29-50	66.1	67.9	86.0					
12[c]	6-5-50	74.0	67.0	69.2					1.4
13	6-12-50	73.0	84.8	108.7					1.4
14[d]	6-19-50	75.0	115.3	125.2					1.5
15[e]	6-26-50	84.0	115.6	97.8					1.1
16[f]	7-3-50	82.5	119.0	130.1					1.4
17	7-10-50	80.5	147.8	143.4		14.1	12.8	1.4	1.5
18[g]	7-17-50	71.5	139.9	133.2	146.5		11.4		1.3
19	7-24-50	70.0	134.1	141.2	146.6	11.5	10.2	2.2	1.4
20	7-31-50	72.5	170.1	165.2	153.9	11.9	16.4	2.8	1.4
21	8-7-50	78.5	157.7	150.8	151.7	12.0	7.9	2.7	1.3
22	8-14-50	79.5	167.2	148.8	149.6	11.9		2.9	1.4
23	8-21-50	66.3	154.5	162.5	156.5	11.3		2.8	1.5
24	8-28-50	53.0	162.3	163.1	156.0	12.2		3.0	1.4
25	9-5-50	76.5	153.2	156.6	142.3	14.8		2.9	1.4
26	9-11-50	57.0	162.6	150.4	139.6	11.1		2.8	1.5
27[h]	9-18-50	61.6	141.8	141.8	150.8	10.7		2.9	1.4
28	9-25-50	60.5	143.3	136.6	155.7	11.7		3.0	1.3
29	10-2-50	55.0	154.9	138.2	135.8	13.1		2.9	1.2
30	10-9-50	54.0	145.8	122.6	145.9	11.8		2.7	1.2

a Cattail tops frozen back 6 to 8 inches.
b Green cattail leaves knocked down to water surface by snow.
c Broad-leaved fruiting bodies beginning to appear.
d Broad-leaved cattail pollinating heavily.
e Broad-leaved cattail pollination 90 percent completed.
f Broad-leaved cattail pollination completed. Female spike black brown.

Final Weight				Percent Dry Matter		Percent Carbohydrate	Specimen Number
Fresh g		Oven-Dry g				Oven-dry	
Shoots	Roots	Shoots	Roots	Shoots	Roots	Roots	
	200.6		52.3		26.1	55.17	1
	215.6		50.7		23.5	54.00	2
	117.8		34.4		29.2	47.37	3
	99.6		27.7		27.8	58.13	4
27.3	90.0	2.7	24.0	9.9	26.7	43.80	5
29.3	215.6	3.2	43.1	10.9	20.0	43.33	6
116.7	399.0	10.0	82.4	8.6	20.7	49.30	7
500.1	384.0	35.9	47.0	7.2	12.2	37.87	8
206.4	225.7	16.2	30.2	7.9	13.4	41.77	9
419.8	217.5	50.5	29.1	12.0	13.4	25.93	10
483.0	305.1	53.4	37.2	11.1	12.2	27.23	11
350.7	407.9	56.2	87.3	16.0	21.4	36.93	12
360.0	278.5	80.2	56.8	22.3	20.4	45.90	13
1106.3	566.5	159.3	68.0	14.4	12.0	34.57	14
550.0	425.8	109.9	72.3	19.9	17.0	40.60	15
646.6	400.4	113.9	53.6	17.6	13.4	38.80	16
943.6	422.9	211.3	59.6	22.3	14.1	47.13	17
753.2	604.4	151.1	102.7	20.1	17.0	48.03	18
652.3	405.5	154.1	74.8	23.6	18.4	46.80	19
784.9	502.4	192.8	99.9	24.6	19.9	49.67	20
623.1	492.8	166.2	103.1	26.7	20.9	50.53	21
636.0	528.2	170.9	123.0	26.9	23.3	60.17	22
611.8	458.6	158.4	104.9	25.9	22.9	59.27	23
593.6	419.3	176.4	113.7	29.7	27.1	61.57	24
495.6	286.2	169.7	80.5	34.2	28.1	59.17	25
521.3	408.2	158.3	117.2	30.4	28.7	60.87	26
445.4	439.7	146.6	134.5	33.9	30.6	62.33	27
507.5	405.6	163.7	111.3	32.3	27.4	64.30	28
362.4	395.5	123.4	98.5	34.0	24.9	57.67	29
240.4	327.6	99.1	94.9	41.2	29.0	59.53	30

g Broad-leaved cattail vegetative tips browned.
h Considerable yellowing in cattails.

Final Weight				Percent Dry Matter		Percent Carbo-hydrate	Specimen Number
Fresh g		Oven-Dry g				Oven-dry	
Shoots	Roots	Shoots	Roots	Shoots	Roots	Roots	
	200.6		52.3		26.1	55.17	1
	215.6		50.7		23.5	54.00	2
	117.8		34.4		29.2	47.37	3
	99.6		27.7		27.8	58.13	4
27.3	90.0	2.7	24.0	9.9	26.7	43.80	5
29.3	215.6	3.2	43.1	10.9	20.0	43.33	6
116.7	399.0	10.0	82.4	8.6	20.7	49.30	7
500.1	384.0	35.9	47.0	7.2	12.2	37.87	8
206.4	225.7	16.2	30.2	7.9	13.4	41.77	9
419.8	217.5	50.5	29.1	12.0	13.4	25.93	10
483.0	305.1	53.4	37.2	11.1	12.2	27.23	11
350.7	407.9	56.2	87.3	16.0	21.4	36.93	12
360.0	278.5	80.2	56.8	22.3	20.4	45.90	13
1106.3	566.5	159.3	68.0	14.4	12.0	34.57	14
550.0	425.8	109.9	72.3	19.9	17.0	40.60	15
646.6	400.4	113.9	53.6	17.6	13.4	38.80	16
943.6	422.9	211.3	59.6	22.3	14.1	47.13	17
753.2	604.4	151.1	102.7	20.1	17.0	48.03	18
652.3	405.5	154.1	74.8	23.6	18.4	46.80	19
784.9	502.4	192.8	99.9	24.6	19.9	49.67	20
623.1	492.8	166.2	103.1	26.7	20.9	50.53	21
636.0	528.2	170.9	123.0	26.9	23.3	60.17	22
611.8	458.6	158.4	104.9	25.9	22.9	59.27	23
593.6	419.3	176.4	113.7	29.7	27.1	61.57	24
495.6	286.2	169.7	80.5	34.2	28.1	59.17	25
521.3	408.2	158.3	117.2	30.4	28.7	60.87	26
445.4	439.7	146.6	134.5	33.9	30.6	62.33	27
507.5	405.6	163.7	111.3	32.3	27.4	64.30	28
362.4	395.5	123.4	98.5	34.0	24.9	57.67	29
240.4	327.6	99.1	94.9	41.2	29.0	59.53	30

g Broad-leaved cattail vegetative tips browned.
h Considerable yellowing in cattails.

March 20, 1950, and continued through October 9, 1950.

For the Denver area, minimum carbohydrate root reserves occurred, in general, from May 22, 1950, until July 31, 1950, for the broad-leaved cattails developing from the growing site inundated by water. For the narrow-leaved cattails developing from the growing site inundated by water, the period between June 5, 1950, and July 24, 1950, was one of low root reserves.

The period May 8, 1950, to July 3, 1950, was one of low root reserves for the broad-leaved cattails developing from the growing site not inundated by water while the period July 3, 1950, to July 24, 1950, showed low root reserves for the narrow-leaved cattails developing from the growing site not inundated by water.

It is well known that growing seasons vary, not only according to altitude and latitude, but from year to year as well. Accordingly, while these dates in general limit the 1950 periods of low root reserve for the cattails developing in the Denver area growth situations they could not be used to determine low root reserves for cattails developing in other sections of the western United States.

Notes Pertaining to Appearance of Fruiting Bodies, Pollination Time, etc.

Study of cattail in this area showed that when plants develop from a growing site inundated by water fruiting bodies do occur.

It should be mentioned here that the broad-leaved cattail site not inundated by water had a drainage ditch passing through it which carried water to a depth of six inches immediately following the occasional heavy spring rains in the area. In no instance, however, did water remain in the drainage channel more than 24 hours after a downpour.

No fruiting bodies developed and, accordingly, no pollination occurred in the narrow-leaved cattails developed from the growing site not inundated by water.

Weekly Water Temperatures Approximately Eight Inches Below Lake Surface

It was interesting to note that cattail growth in the water inundated growing sites began when the water temperature reached 45.8° F. In the developing sites not inundated by water growth development came later. This growth lag appeared to be associated with lower soil temperatures. The narrow-leaved cattail site not inundated by water was appr imately eight weeks behind the water inundated one in plant development.

After each snow and rain storm there was a noticeable drop in lake water temperature. Nevertheless weekly temperatures increased steadily up to the latter part of June when a temperature of 84.0° F was recorded. Warm temperatures held relatively steady until the middle of August when there was a noticeable gradual decline to the final recording of 54.0° F on October 9, 1950.

Height of Plants above Water Surface or Ground Line

Plants developed from the growing sites inundated by water were at maturity approximately 30-50 cm taller than their counterparts developing in non-inundated growth sites.

Nonfruiting broad-leaved plants developing in inundated growth sites were approximately 40 cm taller than fruiting plants developing in similar sites.

In the narrow-leaved and broad-leaved cattail growth site not inundated by water root reserves were at a minimum when the plants had attained a height of approximately 100-130 cm and 50-120 cm above the ground line respectively.

Total Length of Plant Shoots

At maturity, leaf lengths were approximately 30 cm more for non-fruiting than for fruiting broad-leaved cattail plants.

Leaves on plants developed from the growing sites inundated by water were approximately 50-70 cm longer than on similar plants developing in non-inundated growth sites.

Total Length of Seed Stalk

At maturity, in the growing sites inundated by water, leaf length extended beyond the seed stalk approximately 10 cm in the broad-leaved cattails and 30-40 cm in the narrow-leaved cattails.

In general, for both cattail species the period of seed stalk elongation was one of low carbohydrate root reserves.

Length of the Female and Male Spikes

Female and male spike lengths did not increase noticeably from time of their initial field appearance until they had attained full maturity.

Width of Female Spike

The broad-leaved cattail female spike increased rapidly in diameter from an initial 0.9 cm to the maximum diameter of about 2.7 cm, an increase of about two cm over an approximate seven-week period.

The narrow-leaved cattail female spike likewise increased rapidly in diameter from an initial 0.5 cm to the maximum diameter of about 1.7 cm, an increase of about 1.2 cm over an approximate six-week period.

Both species of cattails go through a pronounced depletion of carbohydrate root reserves during this period of rapid expansion of the female spike.

Width of Leaf

Broad-leaved cattail leaves increased rapidly in width from an initial 1.0 cm to the maximum width of about 1.5 cm, an increase of about 0.5 cm over an approximate eight-week period.

Narrow-leaved cattail leaves likewise increased rapidly in width from an initial 0.5 cm to the maximum width of about 0.8 cm, an increase of about 0.3 cm over an approximate six-week period.

It was interesting to note that, in general, both species of cattails attained maximum leaf width immediately preceding their respective periods of low carbohydrate root reserve.

Shoot and Root Fresh Weight

The shoot and root fresh weight samples were limited in size to the amount of cut plant material which could be placed in a six-inch cubical wire basket.

Percentage Dry Matter in Shoots and Roots

In all five cattail growth situations investigated there was a marked tendency for percentage dry matter in roots to be relatively high when percentage carbohydrate in roots was high and similarly to be low when percentage carbohydrate was low.

In contrast to the roots, the percentage dry matter in the shoots, in the five cattail situations investigated, increased apparently at the expense of the carbohydrate root reserves which at the same time were being depleted.

It is apparent that root reserves are at a minimum for the fruiting and nonfruiting broad-leaved cattail plants developing in growing sites inundated by water when the percentage dry matter in the roots is approximately 10 percent. Likewise, root reserves are at a minimum for broad-leaved cattail plants developing in growing sites not inundated by water, and for the narrow-leaved cattail plants developing in both the water inundated and non-inundated sites, when the percentage dry matter in the roots is approximately 15 percent.

It can be seen that by making laboratory fresh, and oven-dry, weights on cattail root samples and calculating percentage dry matter in the same, it would be possible to follow the percentage carbohydrate in roots through the growing season without performing the more time-consuming, but more precise, chemical analyses.

Percentage Readily Hydrolizable Carbohydrate in Oven-Dry Roots

During the winter dormancy period cattail roots had a carbohydrate root reserve of approximately 60-70 percent. As plant development progressed in the three broad-leaved cattail growth situations, a minimum root reserve of about 25 percent was reached. This minimum was followed by a gradual increase of food reserves which continued to the end of the growing season.

In the two narrow-leaved cattail growth situations a similar decrease in root reserves occurred as plant development progressed, followed by the gradual increase of reserve food which continued to the end of the growing season.

It was interesting to note that the minimum readily hydrolizable carbohydrate root reserve obtained for the narrow-leaved cattail was about 40 percent. Field observations indicated that the narrow-leaved cattail roots were more laden with starch than were the roots of their frequent field associates, broad-leaved cattail.

This work indicates that maximum cattail eradication and/or control with minimum time, effort, and cost should be effected if the herbicidal applications are made: (1) between the time of first appearance of the fruiting stalks and when pollination has been completed, (2) when narrow-leaved cattail plants developing in growing site not inundated by water attain a height of 100-130 cm, (3) when broad-leaved cattail plants developing in growing site not inundated by water attain a height of 50-120 cm, (4) during the period between appearance and maximum seedstock elongation, (5) between initial appearance and when broad-leaved cattail female fruiting body attains a diameter of 2.7 cm, (6) between initial appearance and when narrow-leaved cattail female fruiting body attains a diameter of 1.7 cm, (7) when percentage dry matter is approximately 10 percent for roots of broad-leaved cattail developing in sites inundated by water, (8) when percentage dry matter is approximately 15 percent for roots of cattails developing in the growth categories other than in 7 above, (9) when a minimum carbohydrate root reserve of 25 percent is reached for broad-leaved cattail plants, regardless of the growth situation (10) when a minimum carbohydrate root reserve of 45 percent is reached for narrow-leaved cattail plants, regardless of the growth situation.

IDENTIFICATION OF SPECIES

Differences in effect of herbicides on water plants can be accounted for, in part at least, by variation in species or varieties of species present at the time of treatment.

Translocation studies were performed on the following species and varieties of plants (Coulter and Nelson 4, Fassett 8, Fernald 9, Fernald 10, Hotchkiss and Dozier 15, Moore 22, Muenscher 23, Ogden 24, Robinson and Fernald 26, Rydberg 27, St. John 28, Schmeil and Fitschen 30) which personal observations have shown to be some of the most troublesome vascular plant waterweeds which impede irrigation water flow in the United States west of the 100th meridian:

water sedge, *Carex aquatilis* Wahl.

leafy pondweed, *Potamogeton foliosus* Raf. var. *genuinus*

American pondweed, *Potamogeton nodosus* Poiret

gigantic sago pondweed, *Potamogeton pectinatus* L.

slender sago pondweed, *Potamogeton pectinatus* L.

Richardson's pondweed, *Potamogeton richardsonii* (Ar. Benn.) Rydb.

narrow-leaved cattail, *Typha angustifolia* L.

broad-leaved cattail, *Typha latifolia* L.

horned pondweed, *Zannichellia palustris* L.

It will be noted that distinction has been made between slender and gigantic sago pondweeds, both taxonomically known as *Potamogeton pectinatus* L.

It has been observed in the laboratory that the coarse form, so common in flowing waters of the west, is much more resistant to chemicals than is the slender form, more common in the relatively quiet waters of the west. Thus, it seems desirable in this study to make a distinction between the two forms of *Potamogeton pectinatus* L.

MATERIALS AND METHODS

The methods and materials used in making herbicidal treatments can in this study, for convenience, be divided into five sections.

I. Leaf-Tip Immersion Test

In the leaf-tip immersion test (see plates I and II), one cut leaf tip from one plant in each beaker was immersed in commercial undiluted phenoxyacetic acid derivative for 24 hours. The immersed part was then cut off with scissors and the plant placed in the greenhouse for a five-week period. At the end of this period, the amount of living and dead leaf material in immersed leaves, non-immersed leaves on the same plant, and leaves developed from lateral buds, were measured separately in each beaker for length and the combined living and dead material used for weight determinations.

Killing effect on the leaf of which the cut tip was immersed, or on the non-immersed leaves on the same plant, was considered to be of a local type. Killing effect on the leaves developed from lateral buds after the immersion treatments, and absence of new regrowth in the eight-week period following leaf harvest was considered to be evidence of a permanent or systemic type of kill.

Plants used were grown in beakers from lateral buds and were approximately 2-1/2 feet tall at time of test.

The immersion solution is listed for each group of five beakers. The first two numbers in each group of five, e.g., 1-2, 6-7, 11-12, etc., are treatments in which narrow-leaved cattail plants were used. The last three numbers in each group of five, e.g., 3-5, 8-10, 13-15, etc., are treatments in which broad-leaved cattail plants were used.

The arithmetical average for each group of plants treated, i.e., narrow-leaved cattail and broad-leaved cattail, is reported in such a manner that the percentage kill expressed in length and weight can be compared with the non-treated control group which are numbered 35-40.

II. Root-Immersion Test

In the root-immersion test (see plate III), roots of the plants were immersed in a solution containing 10 ppm of phenoxyacetic acid compound for 24 hours, rinsed in three changes of tap water and the plants then put in beakers containing tap water, which in turn were placed in the greenhouse for a five-week period.

At the end of this period, the amounts of living and dead leaf material in each beaker were measured for length and weight. Killing effect on the leaves of these treated plants was considered to be of a local type. Killing effect, as evidenced by absence of new regrowth in the eight-week period following leaf harvest, was considered to be evidence of a permanent or systemic type of kill.

As in the previous test, plants used were grown in beakers from lateral buds and were approximately 2-1/2 feet tall at time of test.

As in the leaf-tip immersion test, the immersion solution is listed for each group of five beakers. The first two numbers in each group of five, e.g., 51-52, 61-62, etc., are treatments in which narrow-leaved cattail plants were used. The last three numbers in each group of five, e.g., 53-55, 63-65, etc., are treatments in which broad-leaved cattail plants were used.

The arithmetical average for each group of plants treated, i.e., narrow-leaved cattail and broad-leaved cattail, is reported in such a manner that the percent kill in length and weight can be compared with the non-treated control group which are numbered 81-85.

III. Aerial Herbicidal Treatment on Plant Materials Transplanted to Buckets of 5-Gallon Capacity

It was desirable to know something about the regenerative powers of broad-leaved cattail plants. In order to investigate this question, 15 basally clipped stocks were measured for bud lengths and individually placed in 3,000 ml beakers, containing only tap water, on October 26, 1949. The first crop of new growth from the buds was measured, recorded, and harvested December 30, 1949. On this and successive dates the number of new buds was counted and amount of growth developing from the new buds was measured, recorded, and harvested. The length of the longest leaf in each new plant developed from the old stock was recorded as shoot length.

On October 18, 1950, the rhizomes were processed, as discussed earlier in the section on seasonal carbohydrate root reserve trends in roots and rhizomes of broad- and narrow-leaved cattails, and the percentage hydrolizable carbohydrate determined as described by

Woodman (37) and Schaffer and Hartmann (31). In this determination for reducing sugars, i.e., reducing substances, the monosaccharides, the disaccharides lactose and maltose and upon hydrolysis sugars yielded by starch, pentosans and various hemicelluloses possess the property of reducing alkaline solutions of metallic salts, such as copper or mercury, oxygen being withdrawn and the metal precipitated either as such or as a lower oxide. Chemical analyses thus showed the amount of readily available carbohydrates still present in cattail rhizomes after between 15 and 20 new and complete plant entities had emerged from the several rootstocks.

Before making herbicidal applications on aerial parts of field grown, broad- and narrow-leaved cattails, the plant materials were transplanted from the field directly to buckets of five-gallon capacity one week before treatment (see plates VI and VII), and with as little root disturbance as possible.

The inside of the containers was painted before use with two coats of coal-tar paint to inhibit rust formation. Exposed surface area measurements were calculated to be 79 square inches for each of the five-gallon buckets.

The buckets containing the transplanted material were filled with tap water and the shoot lengths above the surface of the water in each bucket were measured.

Initially, percentage dead plant material, based on length and weight measurements, was considered a measure of the temporary lethal effects. Absence of green shoot development after treatment and a relatively low percentage carbohydrate, i.e., less than 30 for broad-leaved cattail and less than 40 for narrow-leaved cattail, root reserve three or four weeks after treatment were considered indicative of lasting lethal effects for any particular herbicidal treatment.

At the termination of this particular study it became apparent that in a number of instances treated plants with no green shoot regrowth development three and four weeks after treatment frequently had a relatively high percentage carbohydrate root reserve, and, therefore a considerable regrowth potential.

Aerial herbicidal application was made in each case with the one-quart capacity, model A, Sure Shot pneumatic sprayer.

The quantity of the particular chemical used in this study was determined by computing the difference between the initial amount placed in the sprayer and the amount remaining therein after aerial herbicidal spray application had been made. Initial air pressure in the sprayer for each spraying was 120 pounds per square inch.

Bohmont (2), Grigsby, Churchill, Hamner and Carlson (13) have pointed out the fact that herbicidal actions of 2,4-D and 2,4-5-T are related to the actual acid equivalent of the formulation. Accordingly, systemic herbicidal dosage amounts are, in this study, stated on the acid-equivalent basis.

The chemical compounds used in the various aerial herbicidal sprays were formulated as follows:

1. Alpha benzene hexachloride--300.0 g made up to 2,000 ml with Xylene containing one percent California Spray Chemical Ortho emulsifier no. 5

2. Amine salt of 2,4-D--2.49 g made up to 1,000 ml with water

3. Anhydrous copper sulphate--106.6 g made up to 2,500 ml with water

4. Ester of 2,4-D--2.08 g made up to 1,000 ml with water

5. Ester of 2,4,5-T--2.08 g made up to 1,000 ml with water

6. Pentachlorophenol--200.0 g made up to 3,000 ml with xylene containing one percent California Spray Chemical Ortho Emulsifier no. 5

7.	Polyethanol Rosin Amine 0500 (D-4)	255 ml	Made up to
	Rosin Amine D	45 ml	2,500 ml with
	Rosin Amine D acetate	229.9 g	xylene

8.	Polyethanol Rosin Amine 1100 (D-12	255 ml	Made up to
	Rosin Amine D	45 ml	2,500 ml with
	Rosin Amine D acetate	239.2 g	water

9. Sodium arsenite--185.0 g made up to 2,500 ml with water

10. Sodium chlorate--750.0 g made up to 2,500 ml with water

11. Sodium pentachlorophenate--250.0 g made up to 2,000 ml with water

12. Sodium salt of 2,4-D--4.11 g made up to 4,100 ml with water

13. Sodium salt of 2,4-D--8.23 g made up to 4,100 ml with water

14. Sodium salt of 2,4-D--16.46 g made up to 4,100 ml with water

15. Sodium salt of 2,4-D--36.86 g made up to 3,785 ml with water

16. Sodium trichloroacetate--279.81 g made up to 3,785 ml with water

17. Xylene--1,980 ml to which was added 20 ml (making one percent solution by volume) California Spray Chemical Ortho Emulsifier no. 5, making a total volume of 2,000 ml

Wetting agents used were as follows:

1. Span 20 and Tween 20 (products of Atlas Powder Company)
2. Span 85 and Tween 85 (products of Atlas Powder Company)
3. Vatsol OT-B (product of American Cyanamid Company)

Immediately after the aerial spray treatments, the water in the buckets was siphoned out of the containers with 1/2-inch rubber tubing, the buckets re-filled with water, siphoned out a second time, and again re-filled with water. Flooding of the buckets continued for one minute after they were full to wash out any chemical that might have fallen into the bucket during spraying. Thus, any effect on the root system of the cattails would be due to translocation effects from the above-ground or above-water plant parts.

After the aerial herbicidal treatment had been made on the broad- and narrow-leaved cattail plants they were allowed to remain in their containers on a concrete loading platform located on the north side of a building, in one experiment for three weeks, in the other for four weeks.

At the end of this period of time the amount of living and dead leaf material in each bucket was measured for length and weight. Consideration of the effects of temperature differences on plants in the two tests made it desirable to disregard the number of green shoots developing after treatment as a measure of permanent lethal effect on the treated plants. Percentage hydrolizable carbohydrate root reserve three and four weeks after treatment appeared to be a reliable manifestation of permanent injury brought about in the plants receiving the various herbicidal applications.

Measured percent survival at the termination of these two tests was determined by taking the arithmetical average of percentage dead based on total length and total weight measurements and then subtracting from 100. These figures, as suggested earlier, were considered a measure only of temporary effects on the treated plants.

IV. Aerial Herbicidal Treatment on Plant Materials Transplanted to Metallic Containers of 27-1/2 Gallon Capacity

In the aerial herbicidal treatment on field grown plant materials transplanted a week before treatment into metallic containers of 27-1/2 gallon capacity (see plates VIII, and XII-XXVII), most of the true waterweed, American pondweed, horned pondweed, leafy pondweed, Richardson's pondweed, gigantic sago pondweed, and slender sago pondweed plants used were transplanted from the field directly to the container with as little root disturbance as possible. In some instances tubers of gigantic sago pondweed were planted directly into the soil at the bottom of the tank.

Approximately ninety 27-1/2 gallon and six 7-1/2 gallon metallic containers were used in this study. The larger capacity containers were prepared by cutting 55-gallon metallic drums in half crosswise or lengthwise. The smaller capacity containers were prepared by cutting 15-gallon metallic containers lengthwise. The inside of the containers was painted before use with two coats of coal-tar paint to inhibit rust formation. The exposed surface area measurements were calculated to be 380 square inches for the large round tanks, and 759 square inches for the large long tanks. The small tanks (cut from the 15-gallon containers) were calculated to have an exposed surface area of 336 square inches. These smaller tanks were used only for the untreated controls.

Before each of the various chemical treatments were made, water was siphoned out of the tanks with 1/2-inch rubber tubing. Because the soil in the bottom of the tanks was not perfectly level, small water puddles, up to two inches in depth, remained in the bottom of the planted tanks. This condition, it is believed, simulates that which would prevail when water flow is completely cut off in an irrigation ditch, i.e., complete drainage would not occur because of occasional low spots in the ditch bottom.

Aerial herbicidal applications on the plants in the drained tanks were made with the one-quart capacity model A, Sure Shot pneumatic sprayers. The spray was applied on the flaccid aquatic plants which, in the absence of the usual water supporting medium, were lying on the soil in which they were rooted.

The sprayed plants normally submerged were allowed to remain lying on the soil at the bottom of the tank for a period varying from two to six hours following spraying, to allow the herbicides to penetrate the plant tissues. In the report this is recorded as exposure time.

At the end of this period of time, the tanks with the sprayed plants were filled with tap water and drained immediately. This operation was repeated twice after which the tanks were filled a third time with tap water and flooded for five minutes. The tanks then stood for seven days approximately one meter distant below a lighted 750-watt incandescent lamp.

After the seven-day period under artificial lighting, the water in the tanks was siphoned off and the tanks and plants were moved to an outside sunny exposure next to the greenhouse. The tanks were again filled with tap water and the plants observed for effects of the chemical treatments.

Water was drained off of the chemically untreated control tanks and the plants growing therein were subjected to the same two- to six-hour desiccation as the chemically sprayed tanks, the only difference being that no chemical was applied.

It should be noted that this same uniform technique was used even when using contact chemicals, e.g., copper sulfate, sodium arsenite, etc.

It is believed that by filling and siphoning off the water in the tanks twice and then filling and flooding for five minutes, any herbicide which had not entered the plant in the two- to six-hour exposure period would be washed out of the tank, thus, any effects observed after treatment could be attributed to entry of the chemicals into the flaccid plants during the exposure time when the water was out of the tank.

This washing effect was thought to simulate the washing effect which would occur when water is turned back down an irrigation ditch where rooted aquatic weeds have been sprayed, using a technique similar to the one described for the rooted aquatic weeds growing in the tanks.

The amount of phenoxyacetic acid derivative used on these various tanks was calculated on an acid equivalent pound-per-acre and gallon-per-acre basis. Contact herbicides used were calculated on a pound-per-acre and gallon-per-acre basis.

In some instances, a contact herbicide was applied 24 hours after a systemic herbicide had been used. In other experiments, several weeks elapsed between the two or three separate treatment applications.

In each case, one half of the plants in the control tanks was undisturbed and the remaining half of the plants in the control tanks was clipped to the ground with household scissors. Thus, a comparison can be made between no disturbance, clipping, and chemical treatment.

At the termination of the experiment, the water was siphoned off and an estimation made as to the percentage of the soil area in the bottom of the tank supporting green plant growth of the initial species present in the tank. The soil in the bottom of the tanks was examined for the presence of living underground propagules. From this physical examination estimated percentage survival is reported.

When systemic herbicides were used on both first and second treatments, the summation of the two was reported as pounds per acre for that particular treatment.

In like manner, when the same kind of contact herbicide was used in both first and second treatments, the summation of the two was reported as pounds per acre for that particular treatment.

In order to obtain a quantitative measurement of the effect of the various chemicals used, in several instances the living plant material remaining in the tank at the termination of the experiment was harvested, weighed fresh, oven-dried, and weighed again. This quantity of oven-dried residue remaining was compared with the oven-dried residue in the control tanks in which half the area was clipped each time an aerial herbicidal treatment was made on the experimental tanks. These data are presented with photographs of the tanks to which they pertain.

V. Miscellaneous Tests

It was desirable to know whether 2,4-D would move past the water line when emergent aquatic plants were treated with this herbicidal compound. The following test was then performed to determine if 2,4-D could be detected in the underwater roots of cattail plants, the leaves of which were sprayed with this phenoxyacetic acid derivative.

About 15 selected, pulverized cattail root specimens were extracted with benzene in a Soxhlet extraction apparatus. The benzene extract was evaporated to dryness in a test tube; a few crystals of chromotropic acid (1,8-dihydroxy naphthalene 3,6-disulfonic acid) introduced; two ml of concentrated sulfuric acid added, and the material heated in a glycerine bath at 150° C for 1-1/2 to two minutes. Freed (11) found that when following this procedure a deep wine-purple color develops quite rapidly while heating when 2,4-D is present.

Water sedge plants were treated (see plate XI) with herbicidal concentrations of 2,4-D and 2,4,5-T to observe the effect of these applications on root reserve depletion and leaf kill in the sedges. Accordingly, a procedure was followed similar to that used in transplanting and treating the cattails except that in this instance two containers of 27-1/2 gallon capacity were used and, too, percentage kill was determined by weight measurements only.

In the Appendix, photographs showing the various plant growths before and after systemic herbicidal treatment are presented together with photographs of mechanically clipped and untreated plants so that a visual evaluation may be made of the respective treatments.

Photomicrographs of aquatic plant sections prepared (Corrington, 3, Sass, 29) by the paraffin and celloidin methods (see plates IX and X) are included to show variation in aquatic plant anatomy, particularly the marked difference in amount of cutin, number of stomata, location of chloroplasts, and degree of specialization of the vascular system.

Certain anatomical features peculiar to the species (see plate IV) are shown which should be helpful in effecting accurate field identifications of the waterweeds.

In this report all linear measurements, except where otherwise noted, are made in centimeters, weight measurements in grams, and temperature measurements in degrees Fahrenheit.

DISCUSSION OF RESULTS

I. Leaf-Tip Immersion Test

Results from immersing one cut leaf tip per cattail plant for 24 hours in commercial strength systemic herbicidal stock solution are presented in table 8. These data show the changes in amount of living material in the above-ground plant parts brought about, five weeks after treatment, by the action of certain herbicides passing from the tip of the cut leaf through the plant body.

The isopropyl esters of 2,4,5-T and 2,4-D were more pronounced in their lethal effects on the narrow-leaved cattail than was the triethanolamine salt of 2,4-D.

In the treated, broad-leaved cattail plants, on the other hand, the difference in lethal effects between the ester and salt of 2,4-D was much less pronounced.

Perhaps the most interesting results of this test lie in the lethal effects produced by the apparent passage of the esters into the leaves developed from the initially undeveloped, basally located, lateral buds. It appears that the lethal effect on these leaves was brought about by transmission of the herbicide through the immersed leaf tip past the waterline and into the crown of the plants involved. Associated with this phenomenon is the fact that no shoot regrowth developed in the ester treated plants in the eight-week period

TABLE 8

EFFECT OF IMMERSING ONE LEAF TIP PER CATTAIL PLANT FOR 24 HOURS IN COMMERCIAL STRENGTH SYSTEMIC HERBICIDAL SOLUTION
DATA TAKEN 5 WEEKS AFTER TREATMENT

Plants Treated and Compound Used	Beaker Number	Total Leaf Length: Leaf with Immersed Tip: Dead cm	Living cm	% Dead	Nonimmersed Leaves: Dead cm	Living cm
Narrow-Leaved Cattail						
Typha angustifolia L.						
No treatment	4-5	7.0	114.5	6.0	100.8	258.7
2,4,5-T, Isopropyl ester	6-7	139.1	0.0	100.0	229.0	88.9
2,4-D, Isopropyl ester	11-12	82.0	0.0	100.0	164.1	0.0
2,4-D, Triethanolamine salt	16-17	40.6	91.4	31.1	145.3	35.5
Broad-Leaved Cattail						
Typha latifolia L.						
No treatment	1-3	0.0	162.2	0.0	97.9	516.5
2,4,5-T, Isopropyl ester	8-10	176.3	24.1	87.5	315.5	417.8
2,4-D, Isopropyl ester	13-15	185.3	0.0	100.0	343.5	236.1
2,4-D, Triethanolamine salt	18-20	188.8	0.0	100.0	282.5	311.8

% Dead	Leaves Developed from Lateral Buds: Dead cm	Leaves Developed from Lateral Buds: Living cm	Leaves Developed from Lateral Buds: % Dead	Total Leaf Weight: Dead: Fresh Grams	Total Leaf Weight: Dead: Oven-dry Grams	Total Leaf Weight: Living: Fresh Grams	Total Leaf Weight: Living: Oven-dry Grams	Total Leaf Weight: % Dead: Oven-dry Basis	Shoot Regrowth 9-22-50: Maximum Leaf Length
25.0	0.0	106.0	0.0	1.1	0.4	9.0	2.1	15.0	11.1
70.1	44.2	193.3	23.6	4.6	2.4	6.5	1.8	60.5	0.0
100.0	82.1	340.9	20.0	3.4	1.4	7.0	1.7	44.3	0.0
85.8	0.0	463.5	0.0	2.0	0.9	11.6	2.9	23.6	12.0
12.3	0.0	94.9	0.0	1.5	0.5	23.2	5.2	4.7	0.0
48.8	0.0	299.2	0.0	10.3	6.0	29.5	7.9	43.4	0.0
57.5	76.5	1136.0	16.7	15.6	6.5	37.6	9.1	37.8	0.0
46.7	0.0	372.7	0.0	14.0	5.6	27.1	6.7	41.3	0.4

following the leaf harvest, as is shown by the last column of the table. Both species of cattail treated with the triethanolamine salt of 2,4-D, on the other hand, did show some regrowth during the eight-week period which followed leaf harvest.

This phenomenon is very important in cattail control for, as already mentioned, between 15 and 20 new cattail shoots or plant entities have been seen to emerge from basally clipped broad-leaved cattail stocks over a period of several months.

II. Root-Immersion Test

Results from immersing cattail roots for 24 hours in 10 parts per million of systemic herbicidal solution are presented in table 9. These data show the changes in amount of living material in the above-ground plant parts brought about five weeks after treatment by the action of certain herbicides placed in contact with the roots through the plant body.

Both the ester and salt of 2,4-D were more pronounced in their temporary effects on the narrow-leaved cattail than was the isopropyl ester of 2,4,5-T.

In contrast, the treated broad-leaved cattail plants showed a much less pronounced difference in temporary effects between 2,4-D and 2,4,5-T formulation applications applied in the water immersion solutions.

Perhaps the most interesting results of this test lie in the fact that, while immersion of narrow-leaved cattail roots in 10 parts per million of the various herbicides brought about a pronounced temporary effect, the lasting results, as measured by shoot regrowth eight weeks

TABLE 9

EFFECT OF IMMERSING CATTAIL ROOTS FOR 24 HOURS IN 10 PARTS PER MILLION OF SYSTEMIC HERBICIDAL SOLUTION 5 WEEKS AFTER TREATMENT

Plants Treated and Compound Used	Beaker Number	Total Leaf Length: Dead cm	Total Leaf Length: Living cm	Total Leaf Length: % Dead	Total Leaf Weight: Dead: Fresh Grams	Total Leaf Weight: Dead: Oven-dry Grams	Total Leaf Weight: Living: Fresh Grams	Total Leaf Weight: Living: Oven-dry Grams	Total Leaf Weight: % Dead: Oven-dry Basis	Shoot Regrowth 9-22-50: Maximum Leaf Length
Narrow-leaved cattail										
Typha angustifolia L.										
No treatment	1-2	36.5	332.8	9.9	0.3	0.1	4.7	1.1	8.3	4.2
2,4-D, Isopropyl ester	6-7	214.6	115.0	65.1	1.4	0.8	1.8	0.6	57.1	11.1
2,4-D, Triethanolamine salt	11-12	251.5	82.1	75.4	1.5	0.7	1.1	0.3	70.0	10.0
2,4,5-T, Isopropyl ester	16-17	244.8	376.0	39.4	1.4	0.9	6.9	1.8	33.3	7.2
Broad-leaved cattail										
Typha latifolia L.										
No treatment	3-5	462.8	1794.8	20.0	6.3	3.8	61.1	12.6	23.2	8.7
2,4-D, Isopropyl ester	8-10	250.7	453.8	35.6	4.0	2.4	19.8	3.7	39.3	0.0
2,4-D, Triethanolamine salt	13-15	589.0	1201.6	32.9	11.3	5.9	50.9	10.2	36.7	0.0
2,4,5-T, Isopropyl ester	18-20	351.2	1046.4	25.1	3.8	2.4	48.8	9.6	20.0	0.0

following leaf harvest, showed no suppression of the new growth.

On the other hand, immersion of broad-leaved cattail roots in 10 parts per million of similar herbicides brought about a relatively small temporary effect but rather pronounced lasting results as evidenced by no shoot regrowth eight weeks following leaf harvest, thus indicating effective suppression of the new growth.

It appears, accordingly, that the lasting lethal effect on the broad-leaved cattail leaves was brought about by transmission of the herbicides through the roots and into the crown of the plants involved.

III. Aerial Herbicidal Treatment on Plant Materials Transplanted to Buckets of 5-Gallon Capacity

Results from successive clippings of new regrowth developed from the initial basally clipped broad-leaved cattail root stocks are presented in table 10. These data show certain regrowth changes which take place upon gradual depletion of the carbohydrate root reserves in the initial rootstock.

Between 15 and 20 new cattail entities, capable of independent growth, evolved over a period of several months from one-third of the initial basally clipped stocks used in the test.

In general, with successive clippings, there was (1) a decrease in leaf width of the new plants developed, and (2) a decrease in the number of visible buds remaining.

This study brought out the fact that lateral buds are formed

TABLE 10

NUMBER OF NEW SHOOTS DEVELOPED FROM BASALLY CLIPPED BROAD-LEAVED CATTAIL STALKS

	12-30-49			7-25-50			9-26-50			10-18-50			
Specimen Number	Shoot Length	Average Leaf Width	Number of Visible Buds Remaining	Shoot Length	Average Leaf Width	Number of Visible Buds Remaining	Shoot Length	Average Leaf Width	Number of Visible Buds Remaining	Shoot Length	Average Leaf Width	Number of Visible Buds Remaining	% Carbohydrate Root Reserve
	61.6	0.5	5	71.7	0.6	3	26.4	0.5	5	43.0	0.4	1	
	37.7			54.7			44.5			45.5			
1	14.0			68.4			66.5			28.9			
				62.0			19.1			19.2			
										18.4			
										4.1			
	75.9		9	77.6	0.5	3	32.3	0.5	6	27.1	0.4	3	
	81.9			27.9			53.5			28.0			
2	8.9			51.1			16.5			7.0			
	7.0			51.6						19.0			
										39.9			
	36.8		6	57.2	0.6	7	46.0	0.5	8	51.3	0.4	5	
	8.8			50.4			37.0			24.1			
3	39.4			49.3			21.5			16.0			
	36.8			19.8			35.0			19.5			
										12.1			
										5.8			
	70.2		4	53.7	0.4	2	35.3	0.4	4	35.6	0.4	1	
	57.2			65.7			10.8			28.5			
4				46.7			2.0			13.4			
							39.5						

							59.5 38.4						
5	62.9 44.5 7.6	0.9	3	77.4 29.1 20.2 11.3 12.2 22.4 67.8 45.3 46.8	0.4	1	26.0 42.0 14.0 2.5	0.4	8	26.2 21.0 2.2 8.6 7.4	0.3	5	40.93
6	56.5 7.0		4	38.0 43.1	0.4	1	33.7 7.5 8.5 4.7	0.3	3	15.5 12.8 3.0	0.2	0	35.23
7	47.6 35.6		4	36.2 30.9 49.0	0.4	2	52.7	0.6	2	18.7	0.4	1	46.60
8	55.9		4	51.0 46.1 47.0 34.6	0.5	1	25.0	0.5	6	10.2	0.3	4	49.60
9	67.3 20.3 12.1		3	19.2	0.3	2	28.8 25.7	0.3	2	6.5 6.0	0.2	2	32.13
10	55.2		5	44.1 16.5	0.4	2	37.0 5.7	0.5	3	14.8 14.0	0.4	1	48.77
11	9.5		4	44.2 59.4	0.5	2	Dead	Dead	Dead				
12	27.9 27.9 21.6		2	Dead	Dead	Dead							
13	14.0 3.2		2	Dead	Dead	Dead							
14	8.3 7.0		2	36.5 8.4 21.0	0.2	1	8.0 4.8	0.2	1	3.8 3.6	0.1	0	
15	5.7 6.4 2.5		2	Dead	Dead	Dead							

anew at a rate almost commensurate with new growth. Thus, it can be expected that a similar phenomenon occurs in the field.

Preceding tables show that broad-leaved cattail root reserves vary from about 70 percent in the winter dormant condition to a low of approximately 20 percent when they have been depleted by active plant growth. It can be seen from the last column of table 4 that even after a number of new plants have evolved from the old stock, an appreciable amount of root reserves remains to carry on new growth.

Results of the herbicidal action of certain systemic and contact herbicides on narrow- and broad-leaved cattail plants three and four weeks after treatment are presented in tables 11 and 12 respectively.

The contact herbicides, modified rosin primary amine, pentachlorophenol and sodium trichloroacetate, applied 24 hours after approximately 15 pounds of systemic herbicide had been applied to the same plants, appeared to partially nullify some of the effects usually associated with systemic herbicides.

On the narrow-leaved cattail 25.30 pounds, and on the broad-leaved cattail 41.46 pounds, 2,4-D acid equivalent per acre, were effective in lowering the carbohydrate root reserve to 24.77 and 24.20 percent, respectively, and in both instances this relative carbohydrate root exhaustion (see tables 3-7) effected complete eradication. Untreated plants in similar stage of growth had a carbohydrate root reserve of approximately 60 percent for both species of cattail.

It was interesting to note that the plants treated July 7, and reported in table 11, showed less effects from the systemic herbicide

TABLE 11

HERBICIDAL EFFECT OF CERTAIN SYSTEMIC AND CONTACT HERBICIDES ON NARROW- AND BROAD-LEAVED CATTAIL PLANTS THREE WEEKS AFTER TREATMENT

Plants Treated and Compound Used	Pounds per Acre	Bucket Number	Total Leaf Length: Dead: cm	Total Leaf Length: Living: cm	Total Leaf Length: % Dead
Narrow-leaved cattail					
<u>Typha</u> <u>angustifolia</u> L.					
No treatment		1056	0.0	1087.6	0.0
2,4-D, Isopropyl ester	18.58	1051	701.7	1041.4	40.3
2,4-D, Triethanolamine salt	28.35	1052	141.1	1452.3	8.9
2,4,5-T, Isopropyl ester	9.47	1053	64.2	2031.2	3.1
2,4-D, Na salt	6.67	1054	80.0	428.6	15.7
2,4-D, Na salt	11.24	1055	721.4	200.7	78.2
2,4-D, Na salt	25.30	1057	751.2	0.0	100.0
2,4-D, Na salt	14.06				
*Modified rosin, primary amine	335.0	1058	342.0	166.0	67.3
2,4-D, Na salt	11.95				
*Pentachlorophenol	19.84	1059	305.7	416.9	42.3
2,4-D, Na salt	21.09				
*Trichloroacetate, Na salt	388.2	1060	829.2	351.3	70.2
Broad-leaved cattail					
<u>Typha</u> <u>latifolia</u> L.					
No treatment		1006	438.5	2659.6	14.2
2,4-D, Isopropyl ester	24.04	1001	435.0	1156.0	23.0
2,4-D, Triethanolamine salt	45.37	1002	773.6	798.2	49.2
2,4,5-T, Isopropyl ester	33.51	1003	227.1	2512.5	8.3
2,4-D, Na salt	11.23	1004	576.6	713.5	44.7
2,4-D, Na salt	19.68	1005	1076.6	720.2	59.9
2,4-D, Na salt	41.46	1007	800.9	0.0	100.0
2,4-D, Na salt	17.57				
*Modified rosin, primary amine	418.7	1008	1148.3	1529.3	42.9
2,4-D, Na salt	18.90				
*Pentachlorophenol	31.51	1009	535.0	1638.1	24.6
2,4-D, Na salt	18.98				
*Trichloroacetate, Na salt	349.4	1010	1332.2	1054.9	55.8

*Contact herbicide applied 24 hours after preceding systemic herbicide was applied.

Total Leaf Weight: Dead, Fresh Grams	Dead, Oven-dry Grams	Living, Fresh Grams	Living, Oven-dry Grams	% Dead, Oven-dry Basis	Initial Individual Shoot Height above H_2O Surface cm	Number of Green Shoots Developing after Treatment	Percentage Carbohydrate Root Reserve after Treatment	Measured Percentage Survival
0.0	0.0	28.8	7.1	0.0	67,49	1		100
8.9	5.1	23.5	6.0	50.4	74,60,58	5		55
1.9	1.2	51.4	13.6	8.1	95,77,79	3		92
1.0	0.2	51.8	12.9	1.6	68,84,65,64	6		98
0.9	0.5	19.0	5.0	9.1	86	0		88
12.3	4.8	3.6	0.6	88.9	74,78,48,52	2		16
9.2	5.7	0.0	0.0	100.0	74,51,70,75	0	24,77	0
4.1	3.0	2.0	0.3	90.9	81,74	1		21
7.4	1.8	12.5	2.4	42.8	60,69	0		58
9.9	6.5	11.3	2.4	73.0	82,84,79	2		28
13.1	9.3	89.3	25.9	26.4	81,91,72,86	6		80
7.8	5.3	24.6	6.8	43.8	59,75	3		67
16.3	13.1	21.1	5.3	71.2	74,99	2		40
5.9	3.2	98.7	29.8	9.7	91,105	4		91
10.9	7.0	24.5	7.5	48.3	78,72	2		53
20.9	15.9	25.3	7.6	67.6	86,89,95	2		36
13.4	11.5	0.0	0.0	100.0	86,78	0	24.20	0
24.5	16.7	52.3	16.5	50.3	84,88,103	5		53
12.8	7.9	53.5	15.4	33.9	91,84	3		71
21.9	19.3	28.7	6.2	75.7	91,72,102	3		34

applied than did similar plants treated August 25, and reported in table 12.

This can be accounted for partially, perhaps, by the fact that cooler temperatures prevailed immediately following the herbicidal application on the second group of cattail plants and thus there was less stimulation for new growth in the latter group.

The arithemetical average of the daily maximum, minimum and 8 a.m. temperatures for the two periods was as follows:

July 7 to July 28			August 24 to September 22		
maximum	minimum	8 a.m.	maximum	minimum	8 a.m.
82.3	51.5	68.4	80.0	44.6	62.0

Measurement of percentage survival at the termination of the test is presented in tables 11 and 12.

Because of temperature differences during the two series of tests the comparative value of measured percentage survival of the cattails three weeks after the first test and four weeks after the second test remains uncertain.

In the instance where 3.92 pounds of 2,4-D acid equivalent appeared to bring about a 100 percent kill in the narrow-leaved cattails chemical analysis showed a carbohydrate root reserve of approximately 42 percent. This was one of the few instances in which Vatsol OT-B was used as a wetting agent.

IV. Aerial Herbicidal Treatment on Plant Materials Transplanted to Metallic Containers of 27-1/2 Gallon Capacity

TABLE 12

HERBICIDAL EFFECT OF CERTAIN SYSTEMIC AND CONTACT HERBICIDES ON NARROW- AND BROAD-LEAVED CATTAIL PLANTS FOUR WEEKS AFTER TREATMENT

Plants Treated and Compound Used	Pounds per Acre	Bucket Number	Total Leaf Length		
			Dead cm	Living cm	% Dead
Narrow-leaved cattail					
Typha angustifolia L.					
No treatment		1066	728.0	1159.8	38.6
2,4-D, Isopropyl ester	26.95	1061	860.3	699.5	55.2
2,4-D, Triethanolamine salt	32.28	1062	2354.7	1729.6	57.7
2,4,5-T, Isopropyl ester	19.31	1063	595.7	933.3	39.0
2,4-D, Triethanolamine salt	12.65	1064	963.0	1243.3	43.6
2,4-D, Na salt	3.92	1065	784.1	0.0	100.0
2,4-D, Na salt	13.69	1067	2051.0	1289.7	61.4
2,4-D, Na salt	23.55	1068	318.3	546.3	36.8
2,4-D, Na salt	40.06	1069	654.7	407.5	61.6
Pentachlorophenol	712.0	1070	2634.2	154.7	94.5
Broad-leaved cattail					
Typha latifolia L.					
No treatment		1016	675.5	916.5	42.4
2,4-D, Isopropyl ester	44.80	1011	958.3	724.7	56.9
2,4-D, Triethanolamine salt	37.08	1012	920.1	800.3	53.3
2,4,5-T, Isopropyl ester	29.87	1013	926.2	653.7	58.6
2,4-D, Triethanolamine salt	15.71				
*2,4-D, Isopropyl ester	13.11	1014	981.8	441.4	69.0
2,4-D, Na salt	14.32	1015	1769.2	0.0	100.0
2,4-D, Na salt	17.55	1017	975.1	1213.3	44.6
2,4-D, Na salt	20.75	1018	420.9	722.4	36.8
2,4-D, Na salt	61.15	1019	530.8	823.9	39.2
Pentachlorophenol	571.9	1020	520.9	99.7	83.9

*A mixture of the ester and preceding salt of 2,4-D were used.

Total Leaf Weight: Dead, Fresh Grams	Total Leaf Weight: Dead, Oven-dry Grams	Total Leaf Weight: Living, Fresh Grams	Total Leaf Weight: Living, Oven-dry Grams	Total Leaf Weight: % Dead, Oven-dry Basis	Initial Individual Shoot Height above H_2O Surface cm	Number of Green Shoots Developing after Treatment	Percentage Carbohydrate Root Reserve after Treatment	Measured Percentage Survival
5.1	4.0	27.0	10.2	28.2	90,83,62,115,110	1	58.67	67
5.3	4.8	18.1	8.0	37.5	81,118,116	0		54
23.8	14.6	64.3	21.3	40.7	120,71,131,141,108, 130,90,153	1		51
4.5	3.3	31.6	10.2	24.4	124,100,130	0		68
12.4	7.2	40.5	13.7	34.4	51,93,142,99,116, 119	1	60.80	61
7.3	6.5	0.0	0.0	100.0	112,83	0	42.13	0
42.4	19.5	67.8	22.9	46.0	112,142,108,168, 143	1	65.63	46
2.7	2.1	11.7	4.5	31.8	89,45,80	0		66
6.7	4.7	11.5	4.5	51.1	102,108,87	0		44
42.3	23.0	1.0	0.6	97.5	135,125,129,113, 91,84	4	60.30	4
15.4	7.7	43.9	15.8	32.8	121,22,110	0	56.77	62
21.6	9.3	25.7	10.1	47.9	109,86,83,27	0		48
22.7	10.8	33.0	11.5	48.4	77,112,85,56,116, 87	0		49
12.1	7.0	25.0	7.2	49.3	83,94,95,114,76	0		46
20.2	13.7	19.5	7.8	63.7	116,92,120,99	1	56.53	34
85.7	37.1	0.0	0.0	100.0	136,153,112,133	0	52.50	0
53.9	22.1	70.4	24.5	47.4	150,153,139	0	59.20	54
13.9	7.4	35.6	12.4	37.4	120,90,86	0		63
12.5	4.7	31.5	9.4	33.3	90,23,90,70	0		64
16.0	9.0	1.3	0.2	97.8	126,79	3	54.97	9

The submerged aquatic plants treated, systemic and contact herbicides used, their rates, in pounds per acre acid equivalent basis, and estimated percentage survival are presented in table 13.

At the conclusion of the experiment the soil in the bottom of the tanks was examined for the presence of living underground propagules and from this physical examination the following observations were made on the treated waterweeds:

True Waterweed

With one treatment.

5.09 pounds of 2,4-D effected complete eradication.

8.42 pounds 2,4,5-T effected complete eradication.

With two treatments.

11 pounds 2,4,5-T, followed seven weeks later by 9 pounds 2,4,5-T, effected complete eradication.

Leafy Pondweed

With one treatment.

5 pounds of 2,4-D effected complete eradication.

With two treatments.

5.5 pounds of 2,4-D followed five weeks later by 3.5 pounds 2,4-D effected complete eradication.

79 pounds of anhydrous copper sulphate followed three weeks later by 116 pounds of anhydrous copper sulphate showed no visible control or eradication effects seven weeks after second treatment.

American Pondweed

With one treatment.

6 pounds of 2,4-D effected good control with medium infestations.

TABLE 13

AMOUNT, IN POUNDS PER ACRE, OF PHENOXYACETIC ACID AND OTHER COMPOUNDS USED ON THE AQUATIC AND MARSH PLANTS, LISTED TOGETHER WITH THE ESTIMATION OF PERCENTAGE OF SURVIVAL AT THE TERMINATION OF TEST

Plants Treated	Pounds per Acre Acid Equivalent	Compound	Estimated Percent Survival
True waterweed	32.36	2,4-D, Sodium salt	0
Anacharis canadensis	21.73	2,4-D, Sodium salt	0
(Michx.) Planchon	19.94	2,4,5-T, Isopropyl ester	0
	13.62	2,4-D, Triethanolamine salt	100
	13.40	2,4-D, Triethanolamine salt	0
*	12.42	2,4-D, Isopropyl ester 2,4-D, Triethanolamine salt	30
	11.64	2,4-D, Isopropyl ester	15
	11.30	2,4-D, Triethanolamine salt	0
	8.42	2,4,5-T, Isopropyl ester	0
	5.09	2,4-D, Sodium salt	0
Leafy pondweed	195.04	Anhydrous copper sulfate	100
Potamogeton foliosus	21.87	2,4-D, Sodium salt	0
Raf.	14.80	2,4-D, Triethanolamine salt	0
	13.58	2,4-D, Triethanolamine salt	0
	11.90	2,4,5-T, Isopropyl ester	0
	11.18	2,4-D, Isopropyl ester	0
	10.35	2,4-D, Isopropyl ester	0
	9.21	2,4-D, Isopropyl ester	0
	8.18	2,4,5-T, Isopropyl ester	0
	6.87	2,4-D, Sodium salt	0
	6.72	2,4-D, Triethanolamine salt	0
	5.65	2,4-D, Isopropyl ester	5
	4.93	2,4-D, Sodium salt	0
	3.49	2,4,5-T, Isopropyl ester	85
American pondweed	1277.62	Alpha benzene hexachloride	5
Potamogeton nodosus	491.99	Anhydrous copper sulfate	40
Poiret	16.80	2,4,5-T, Isopropyl ester	5
	13.62	2,4-D, Triethanolamine salt	2
	11.76	2,4-D, Isopropyl ester	5
	11.40	2,4-D, Triethanolamine salt	5
	9.36	2,4-D, Isopropyl ester	5
	9.21	2,4,5-T, Isopropyl ester	60
Gigantic sago pondweed	37.60	2,4-D, Sodium salt	5
Potamogeton pectinatus	22.48	2,4-D, Triethanolamine salt	5
L.	21.58	2,4-D, Sodium salt	5
	20.37	2,4-D, Triethanolamine salt	5

TABLE 13--Continued

Plants Treated	Pounds per Acre Acid Equivalent	Compound	Estimated Percent Survival
Gigantic sago pondweed	17.52	2,4,5-T, Isopropyl ester	5
Potamogeton pectinatus	16.61	2,4-D, Isopropyl ester	10
L.--Continued	15.66	2,4-D, Isopropyl ester	10
	13.62	2,4-D, Triethanolamine salt	5
	13.53	2,4-D, Triethanolamine salt	30
	11.37	2,4-D, Isopropyl ester	20
	11.35	2,4-D, Triethanolamine salt	2
	11.30	2,4-D, Isopropyl ester	20
	10.85	2,4-D, Isopropyl ester	1
	10.62	2,4,5-T, Isopropyl ester	20
	10.08	2,4,5-T, Isopropyl ester	75
	8.83	2,4,5-T, Isopropyl ester	85
	8.11	2,4,5-T, Isopropyl ester	2
	5.65	2,4-D, Isopropyl ester	70
	5.48	2,4-D, Sodium salt	15
Slender sago pondweed	517.14	Sodium arsenite	25
Potamogeton pectinatus	333.69	Anhydrous copper sulfate	100
L.	196.59	Anhydrous copper sulfate	100
Richardson's pondweed	27.12	2,4-D, Triethanolamine salt	15
Potamogeton richardson-	22.57	2,4-D, Isopropyl ester	10
ii (Ar. Benn.) Rydb.	15.07	2,4-D, Isopropyl ester	85
	11.26	2,4-D, Triethanolamine salt	2
	5.88	2,4,5-T, Isopropyl ester	100
Horned pondweed	806.38	Alpha benzene hexachloride	0
Zannichellia palustris	446.98	Anhydrous copper sulfate	100
L.	356.12	Sodium arsenite	40
	328.30	TCA, Sodium salt	0
	21.87	2,4-D, Sodium salt	0
	21.53	2,4-D, Isopropyl ester	0
	21.51	2,4-D, Sodium salt	20
	13.53	2,4-D, Triethanolamine salt	0
	13.30	2,4-D, Triethanolamine salt	30
*	12.42	2,4-D, Triethanolamine salt	
		2,4-D, Isopropyl ester	0
	11.34	2,4-D, Isopropyl ester	10
	10.77	2,4-D, Isopropyl ester	0
	8.72	2,4,5-T, Isopropyl ester	50
	7.20	2,4,5-T, Isopropyl ester	0

*Pounds consists of equal parts of isopropyl ester and triethanolamine salt.

9.5 pounds of 2,4-D effected good control with heavy infestations.

With two treatments.

5.5 pounds of 2,4-D followed five weeks later by 4 pounds of 2,4-D effected 95 percent eradication.

133 pounds of anhydrous copper sulphate followed five weeks later by 359 pounds of anhydrous copper sulphate effected 60 percent control or eradication seven weeks after second treatment.

792 pounds of alpha benzene hexachloride followed five weeks later by 486 pounds of alpha benzene hexachloride effected 95 percent control or eradication seven weeks after second treatment.

Gigantic Sago Pondweed

With one treatment.

11 pounds of either 2,4-D or 2,4,5-T effected good control.

With two treatments.

6 pounds of 2,4-D followed seven weeks later by 5 pounds of 2,4-D effected 99 percent eradication.

8 pounds of 2,4,5-T followed one day later by 434 pounds of modified rosin primary amine effected 98 percent eradication.

With three treatments.

13.5 pounds of 2,4-D followed one day later by 820 pounds of alpha benzene hexachloride, followed six weeks later by 547 pounds of alpha benzene hexachloride effected 95 percent eradication.

11.5 pounds of 2,4-D followed one day later by 820 pounds of sodium chlorate, followed six weeks later by 820 pounds of sodium chlorate effected 80 percent eradication.

11 pounds of 2,4-D followed one day later by 370 pounds of trichloroacetate, followed six weeks later by 10.5 pounds of 2,4-D effected 95 percent eradication.

16 pounds of 2,4-D followed one day later by 648 gallons of Xylene and 6.5 gallons of California Spray Ortho no. 5, followed six weeks later by 21.5 pounds of 2,4-D effected 95 percent eradication.

Slender Sago Pondweed

<u>With two treatments.</u>

152 pounds of anhydrous copper sulphate followed three weeks later by 182 pounds of anhydrous copper sulphate effected no visible control or eradication seven weeks after second treatment.

242 pounds sodium arsenite followed four weeks later by 275 pounds sodium arsenite effected no visible control or eradication seven weeks after second treatment.

Richardson's Pondweed

<u>With one treatment.</u>

22.5 pounds of 2,4-D effected 90 percent eradication.

<u>With two treatments.</u>

7.0 pounds of 2,4-D followed seven weeks later by 4.5 pounds of 2,4-D effected 98 percent eradication.

The triethanolamine salt of 2,4-D was appreciably more effective than its isopropyl ester in bringing about Richardson's pondweed kill.

Horned Pondweed

<u>With one treatment.</u>

7.2 pounds of 2,4,5-T effected complete eradication.

806 pounds of alpha benzene hexachloride, 638 gallons of xylene, 6.5 gallons of California Spray Ortho no. 5 effected complete eradication.

<u>With two treatments.</u>

6.0 pounds of 2,4-D followed seven weeks later by 5.0 pounds of 2,4-D effected complete eradication.

328 pounds of trichloroacetate followed 12 weeks later by 356 pounds of pentachlorophenol effected complete eradication.

151 pounds of sodium arsenite followed four weeks later by 205 pounds of sodium arsenite effected 60 percent eradication.

216 pounds of anhydrous copper sulfate followed four weeks later by 231 pounds of anhydrous copper sulphate effected no visible control or eradication seven weeks after second treatment.

Phenoxyacetic acid treatments followed 24 hours later with contact herbicides seemed to be less effective in control or eradication than the phenoxyacetic acid treatment without any following contact herbicidal treatment. Systemic herbicidal applications made in repeat treatments appeared to be more effective than when the same quantity was applied as a single treatment.

In general, the following physical phenomena were observed for the phenoxyacetic acid treated submerged aquatic vascular plants:

> One week after treatment stems and leaves showed pronounced curvatures.
>
> Four weeks after treatment chlorophyll depletion was apparent with most leaves and stems brown, and apparently dead.
>
> Six weeks after treatment regrowth, if any, developed from latent propagules, e.g., buds, seeds, etc.

It was interesting to note that some survival occurred in all of the treated tanks containing American, gigantic sago, and Richardson's pondweeds, even though large quantities of systemic herbicides were used.

It has been observed by Moore (22) that when tubers occur in twos, as is the case with *Potamogeton pectinatus*, only the larger one develops the shoot. The smaller tuber does not sprout unless it becomes detached. In that case only, it develops an individual plant.

Potamogeton nodosus accomplishes vegetative propagation also by subterranean scaly buds which generally grow in pairs at the end of the rootstock.

Potamogeton pectinatus seeds were gathered July 12, 1949, from the Federal Center lake at Denver, Colorado, and kept in cold storage through the winter. On April 19, 1950, 100 seeds were placed in a covered 2-ounce jar containing tap water, which in turn was placed in the greenhouse to observe germination.

Germination proceeded as follows:

Germination Date	Number of Germinated Seeds Removed from Jar
4-25-50	18
5-1-50	2
5-5-50	3
5-9-50	2
5-12-50	2
5-15-50	2
5-22-50	1
6-2-50	0
6-16-50	0
7-10-50	3

Apparently, the systemic herbicides did kill the above-ground vegetative growth present at the time of tank treatments. The percentage survival, present at the termination of the experiment, appears to have come from latent bud propagules or seeds which had not started growth at the time of aerial herbicidal treatment.

This work suggests a new, effective and economically practical technique for applying phenoxyacetic acid compounds on submerged waterweeds growing in irrigation ditches. This method consists of the following steps: (1) shut off irrigation water flow and allow maximum possible gravity drainage to obtain in ditch bottom; (2) apply aerial herbicidal spray of 2,4-D or 2,4,5-T, using a wetting agent, on the unsupported waterweeds lying in the bottom of the gravity drained ditch; (3) allow two to six hours for absorption of chemical by water plants; and (4) turn water back into irrigation ditch.

V. Miscellaneous Tests

<u>Detection of 2,4-D in roots of top-treated cattail plants.</u>

In the test performed to determine presence of 2,4-D in the roots of top-treated cattail plants, 9 out of 14 of the cattail roots examined gave the color reaction which indicated presence of 2,4-D. This indicates that the waterline as such does not act as a barrier to the passage of 2,4-D through cattail tissues.

<u>Effect of systemic herbicidal applications on water sedge.</u>

Results showing depletion of carbohydrate root reserves as well as leaf killing effect in water sedge plants treated with different systemic herbicides are presented in table 14.

TABLE 14

DEPLETION OF CARBOHYDRATE ROOT RESERVES IN WATER SEDGE PLANTS TREATED WITH DIFFERENT SYSTEMIC HERBICIDES

Herbicidal Compound	Pounds per Acre Acid Equivalent	Percentage Carbohydrate 7 Weeks Following Treatment	Measured Percentage Survival
No treatment		45.87	100
2,4-D, Isopropyl ester and *Triethanolamine salt	35.52	24.30	8
2,4,5-T, Isopropyl ester	44.68	24.47	21

*Applied approximately in the proportion of 6 parts salt to 1 part ester.

Systemic herbicidal application in both instances decreased the carbohydrate root reserve by approximately 50 percent and effected an approximate 90 and 80 percent kill when using 2,4-D at a rate of 35.52 pounds and 2,4,5-T at a rate of 44.68 pounds acid equivalent per acre, respectively.

This work indicates that systemic herbicidal treatments on water sedge plants can be used to effectively deplete the carbohydrate root reserves and thereby bring about a permanent kill of the treated plants.

SUMMARY

In order to grow diversified crops on much of the land in the western United States it is necessary to supplant the moisture provided by nature in the form of rain, snow, etc., with additional water which reaches farm lands through established irrigation canal distribution systems. These systems frequently support heavy growth of vascular plants which prevent or slow down the passage of water. Since reducing the carrying capacity of a canal makes it necessary to deprive some potentially crop-producing land of the required water to bring the crop to a satisfactory harvest, it is imperative to keep the waterways open.

This thesis is a report of certain pertinent investigations which suggest improved and more effective field techniques to accomplish a solution of the problem at hand.

In the leaf-tip immersion test the isopropyl ester of 2,4,5-T and 2,4-D were more pronounced in their lethal effects, both temporary and lasting, on the narrow-leaved cattail than was the triethanolamine salt of 2,4-D.

Lethal effects of the ester of 2,4-D appeared to be transmitted through the immersed leaf tip past the waterline, and into the crown of the cattail plants. Associated with this phenomenon is the fact that no shoot regrowth developed in the ester treated plants.

The immersion of broad-leaved cattail roots in 10 parts per

million of the salt and ester formulations of 2,4-D and the ester formulation of 2,4,5-T, brought about lasting results evidenced by no shoot regrowth eight weeks following leaf harvest.

It is a common occurrence for basally clipped broad-leaved cattail rootstocks placed in beakers of water each to evolve between 15 and 20 new cattail entities capable of independent growth.

Contact herbicides on cattails, applied 24 hours after approximately 15 pounds of systemic herbicide had been applied, appeared to nullify the more lasting effects of the systemic herbicides. Systemic herbicidal applications made in repeat treatments appeared to be more effective than when the same quantity was applied as a single treatment.

On the narrow-leaved cattail 25.30 pounds, and on the broad-leaved cattail 41.46 pounds, acid equivalent, per acre were effective in lowering the carbohydrate root reserve to 24.77 and 24.20 percent, respectively. Untreated plants in a similar stage of growth had a carbohydrate root reserve of approximately 60 percent for both species of cattail.

When aerial herbicidal treatments were made the following single or repeated 2,4-D applications were effective in obtaining complete, or nearly complete, eradication of the waterweeds growing in the soil bottom of the treated tanks.

Name of Plant	Pounds per Acre	Number of Treatments	Percent Eradication
Narrow-leaved Cattail	25	1	100
Broad-leaved Cattail	41	1	100
True Waterweed	5	1	100
Water Sedge	27	1	85
Leafy Pondweed	5	1	100
American Pondweed	10	1	95
Gigantic Sago Pondweed	20	2	95
Richardson's Pondweed	12	2	98
Horned Pondweed	11	2	100

It appears that phenoxyacetic acid derivative applications on submerged aquatic plants should be made before the plants reach the fruiting stage.

Broad- and narrow-leaved cattail roots showed considerable variation in the amount of carbohydrates present during the growing season. Highest carbohydrate was present during the winter dormancy period and lowest carbohydrate was associated with production and maturation of male and female fruiting bodies. Without exception it can be said that root reserves are low from the time of the first appearance of the fruiting stocks until pollination has been completed. However, in some cattail growing sites fruiting bodies are entirely lacking and, accordingly, other above-ground phenomenon, associated with low root reserves, must be used to determine optimum time for treatment to obtain maximum cattail control or possible eradication with minimum time, effort, and cost.

Cattail growth in the water inundated growing sites began when the rising spring water temperature reached approximately 46° F.

In the narrow-leaved and broad-leaved cattail growth sites not inundated by water root reserves were at a minimum when the plants had attained a height of approximately 100-130 cm and 50-120 cm above the ground line respectively.

In general, for both cattail species the period of seed stalk elongation and rapid expansion of the female spike was one of low carbohydrate root reserves.

Both species of cattails attained maximum leaf width immediately preceding their respective periods of low carbohydrate root reserve.

In all five cattail growth situations investigated there was a marked tendency for percentage dry matter in roots to be relatively high when percentage carbohydrate in roots was high and similarly to be low when percentage carbohydrate was low.

In contrast to the roots, the percentage dry matter in the shoots, in the five cattail situations investigated, increased apparently at the expense of the carbohydrate root reserves which at the same time were being depleted.

The chromotropic acid test indicated 2,4-D to be present in the roots of 9 of 14 cattail samples taken from plants receiving aerial applications of 2,4-D. This indicates that the waterline is not a barrier to the passage of 2,4-D through the vascular tissue of aquatic plants.

LITERATURE CITED

1. Balcom, R. B. Control of Weeds on Irrigation Systems. United States Department of Interior, Bureau of Reclamation, Washington, 140 pp. 1949.

2. Bohmont, D. W. Using 2,4-D in Wyoming. Wyoming Agricultural Experiment Station, Laramie, Bull. 291, 1949.

3. Corrington, J. D. Working with the Microscope. McGraw-Hill Book Company, New York, 418 pp. 1941.

4. Coulter, J. M., and A. Nelson. New Manual of Botany of the Central Rocky Mountains. American Book Company, New York, 646 pp. 1909.

5. Crafts, A. S. Control of aquatic and ditchbank weeds. California Agricultural Extension Service, Davis, Circ. 158, 1949.

6. Eames, A., and L. H. MacDaniels. An Introduction to Plant Anatomy. McGraw-Hill Book Company, New York, 309-314. 1925.

7. Evans, L. S., J. W. Mitchell, and R. W. Heinen. Using 2,4-D safely. United States Department of Agriculture, Washington, Farm. Bull. 2005, 1948.

8. Fassett, N. C. A Manual of Aquatic Plants. McGraw-Hill Book Company, New York, 382 pp. 1940.

9. Fernald, M. L. The linear-leaved North American species of Potamogeton, Section Axillares, Mem. Amer. Acad. Arts & Sci., 17(1):1-183. 1932.

10. Fernald, M. L. Gray's Manual of Botany. ed. 8, American Book Company, New York, 1632 pp. 1950.

11. Freed, V. H. Qualitative reaction for 2,4-dichlorophenoxyacetic acid. Science. 107: 98-99, 1948.

12. Freeland, R. O. Effects of 2,4-D and other growth substances on photosynthesis and respiration in Anacharis. Bot. Gaz.111:319-324, 1950.

13. Grigsby, B. H., B. R. Churchill, C. L. Hamner, and R. F. Carlson, Chemical weed control. Michigan Agricultural Experiment Station, East Lansing, Circ. Bull. 214, 1949.

14. Hall, T. F., and A. D. Hess. Studies on the use of 2,4-D for the control of plants in a malaria control program. J. Nat. Mal. Soc. 6: 99-116, 1947.

15. Hotchkiss, N., and H. L. Dozier. Taxonomy and distribution of N. American cat-tails. Amer. Midland Naturalist. 41(1): 237-254, 1949.

16. Lange, N. A. Handbook of Chemistry. Handbook Publishers, Inc., Sandusky, Ohio, 1232-1239. 1944.

17. Lepper, H. A., (Chairman). Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists. Association of Official Agricultural Chemists, Washington, 932 pp. 1945.

18. Loomis, W. E., and C. A. Shull. Methods in Plant Physiology. McGraw-Hill Book Company, New York, 472 pp. 1937.

19. Miller, E. C. Plant Physiology. McGraw-Hill Book Company, New York, 776. 1938.

20. Mitchell, J. W., and J. W. Brown. Effect of 2,4-dichlorophenoxyacetic acid on the readily available carbohydrate constituents in annual Morning-glory. Bot. Gaz. 107: 120-129, 1945.

21. ______________, and ______________. Movement of 2,4-dichlorophenoxyacetic acid stimulus and its relation to the translocation of organic food materials in plants. Bot. Gaz. 107: 393-407, 1946.

22. Moore, E. The potamogetons in relation to pond culture. United States Department of Commerce, Bureau of Fisheries, Washington, Bull. 33, 1915.

23. Muenscher, W. C. Aquatic Plants of the United States. Comstock Publishing Company, Inc., Ithaca, New York, 374 pp. 1944.

24. Ogden, E. C. The broad-leaved species of Potamogeton of North America north of Mexico. Rhodora. 45: 57-105, 109-163, 171-214, 1943.

25. Rasmussen, L. W. The physiological action of 2,4-dichlorophenoxyacetic acid on dandelion, Taraxacum officinale. Plant Physiol. 22: 377-392, 1947.

26. Robinson, B. L., and M. L. Fernald. Gray's New Manual of Botany. ed. 7, American Book Company, New York, 926 pp. 1908.

27. Rydberg, P. A. Flora of the Rocky Mountains and Adjacent Plains. P. A. Rydberg, New York, 1110 pp. 1917.

28. St. John, H. A revision of the North American species of Potamogeton of the Section Coleophylli. Rhodora. 18: 121-138, 1916.

29. Sass, J. E. Elements of Botanical Microtechnique. McGraw-Hill Book Company, New York, 222 pp. 1940.

30. Schmeil, O., and J. Fitschen. Flora von Deutschland. Quelle and Meyer Publishing Company, Leipzig, Germany, 439 pp. 1916.

31. Schaffer, P. A., and A. F. Hartmann. The iodometric determination of copper and its use in sugar analysis. J. Biol. Chem. 45: 365-373, 1920-21.

32. Smith, F. G., C. L. Hamner, and R. F. Carlson. Changes in food reserves and respiratory capacity of bindweed tissues accompanying herbicidal action of 2,4-dichlorophenoxyacetic acid. Plant Physiol. 22: 58-65, 1947.

33. Speirs, J. M. Summary of literature on aquatic weed control. Can. Fish Cult. 3(4): 20-32, 1948.

34. Surber, E. W., C. E. Minarik, and W. B. Ennis, Jr. The control of aquatic plants with phenoxyacetic compounds. Progressive Fish-Culturist. 9(7):148, 1947.

35. Thimann, K. V. Use of 2,4-dichlorophenoxyacetic acid herbicides on some woody tropical plants. Bot. Gaz. 109: 334-340, 1948.

36. Weaver, R. J., and H. R. DeRose. Absorption and translocation of 2,4-dichlorophenoxyacetic acid. Bot. Gaz. 107: 509-521, 1946.

37. Woodman, A. G. Food Analysis. McGraw-Hill Book Company, New York, 607 pp. 1941.

APPENDIX

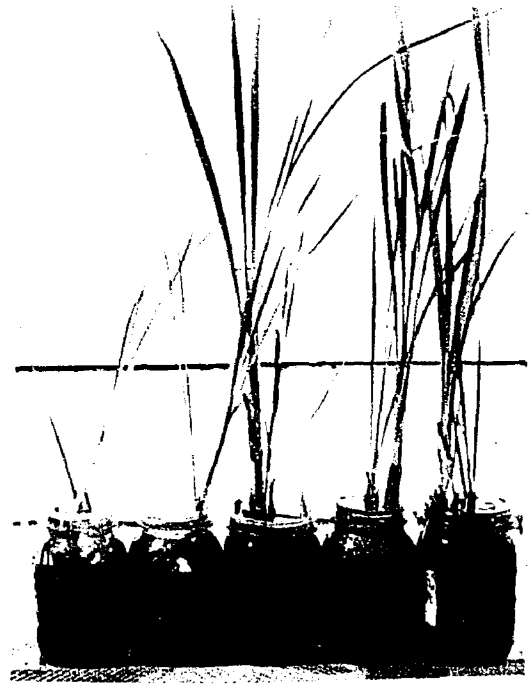
Side view

Aerial view

Plate I. Arrangement for immersion of broad- and narrow-leaved cattail leaf tips (one tip per plant) in jars of commercial herbicidal solution for 24 hours.

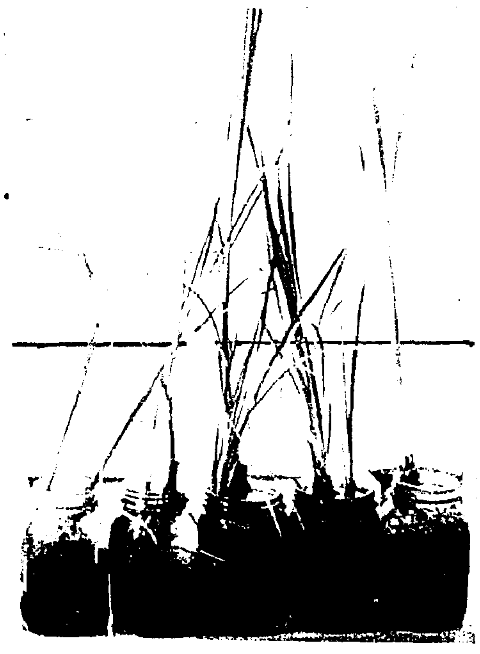
No treatment

1 2 3 4 5

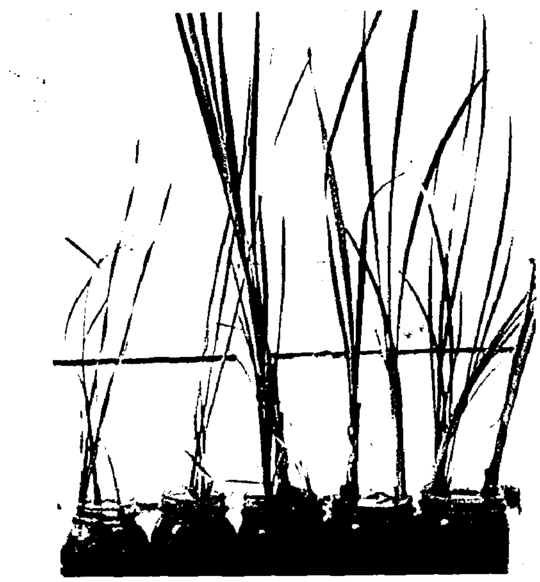


2,4,5-T isopropyl ester

6 7 8 9 10



2,4-D, triethanolamine salt
11 12 13 14 15

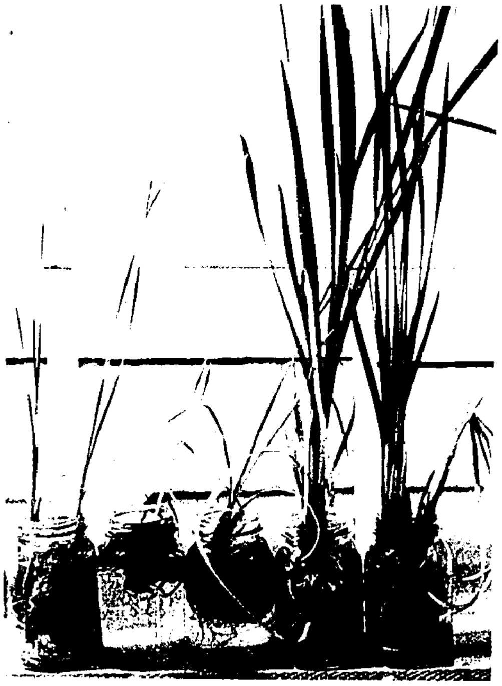


2,4-D, isopropyl ester
16 17 18 19 20

Nontreated
1-3 broad-leaved cattail
4-5 narrow-leaved cattail

Treated
6-7, 11-12, 16-17 narrow-leaved cattail
8-10, 13-15, 18-20 broad-leaved cattail

Plate II. Five weeks after cattail cut leaf tips were immersed in jars of commercial herbicidal solution for 24 hours.

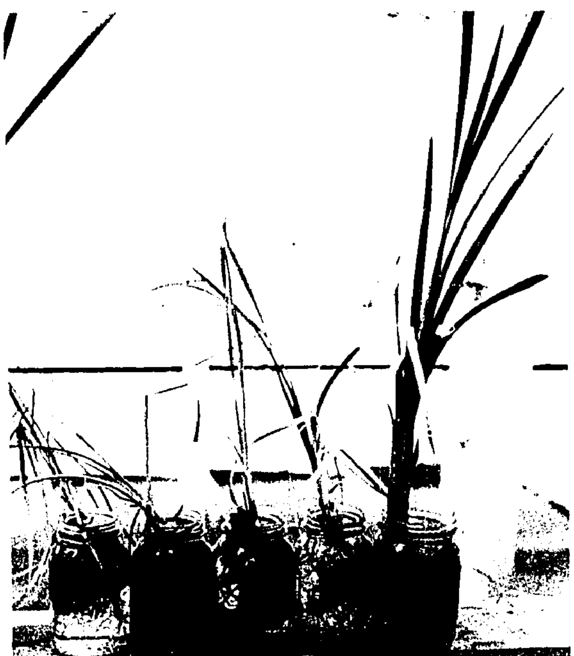


No treatment

1 2 3 4 5

2,4-D, isopropyl ester

6 7 8 9 10



2,4-D, triethanolamine salt

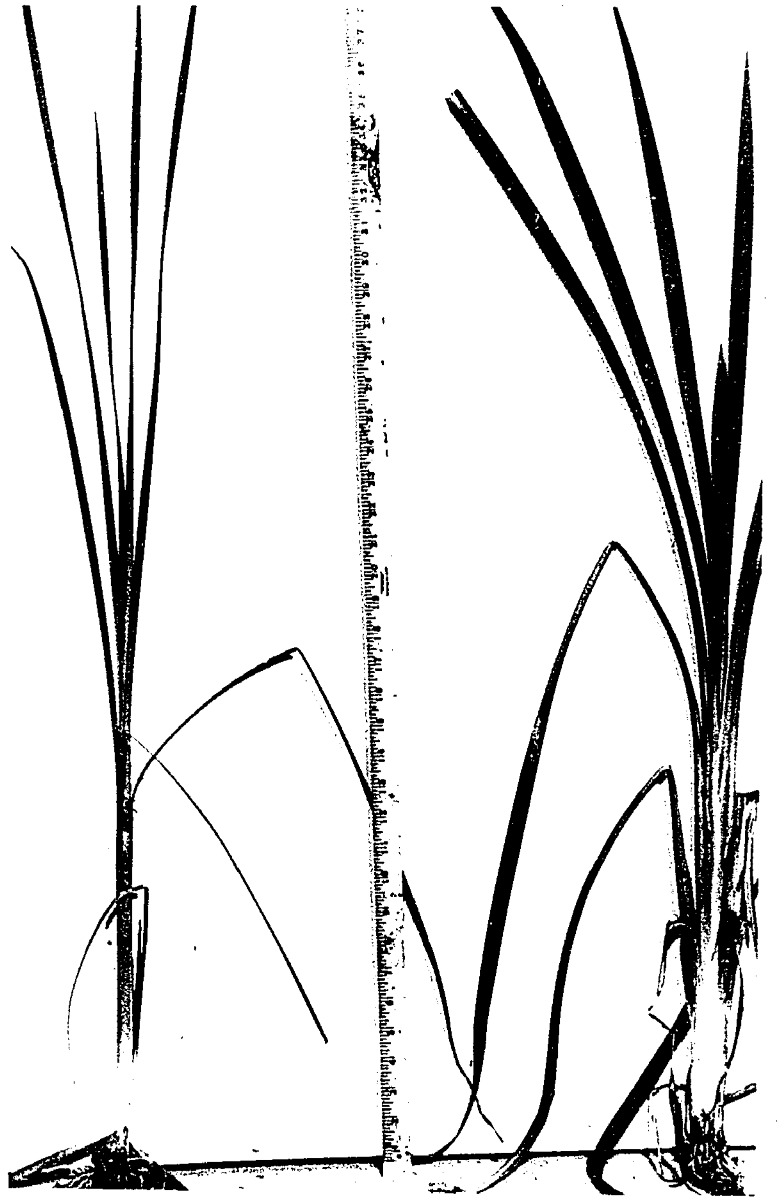
11 12 13 14 15

2,4,5-T, isopropyl ester

16 17 18 19 20

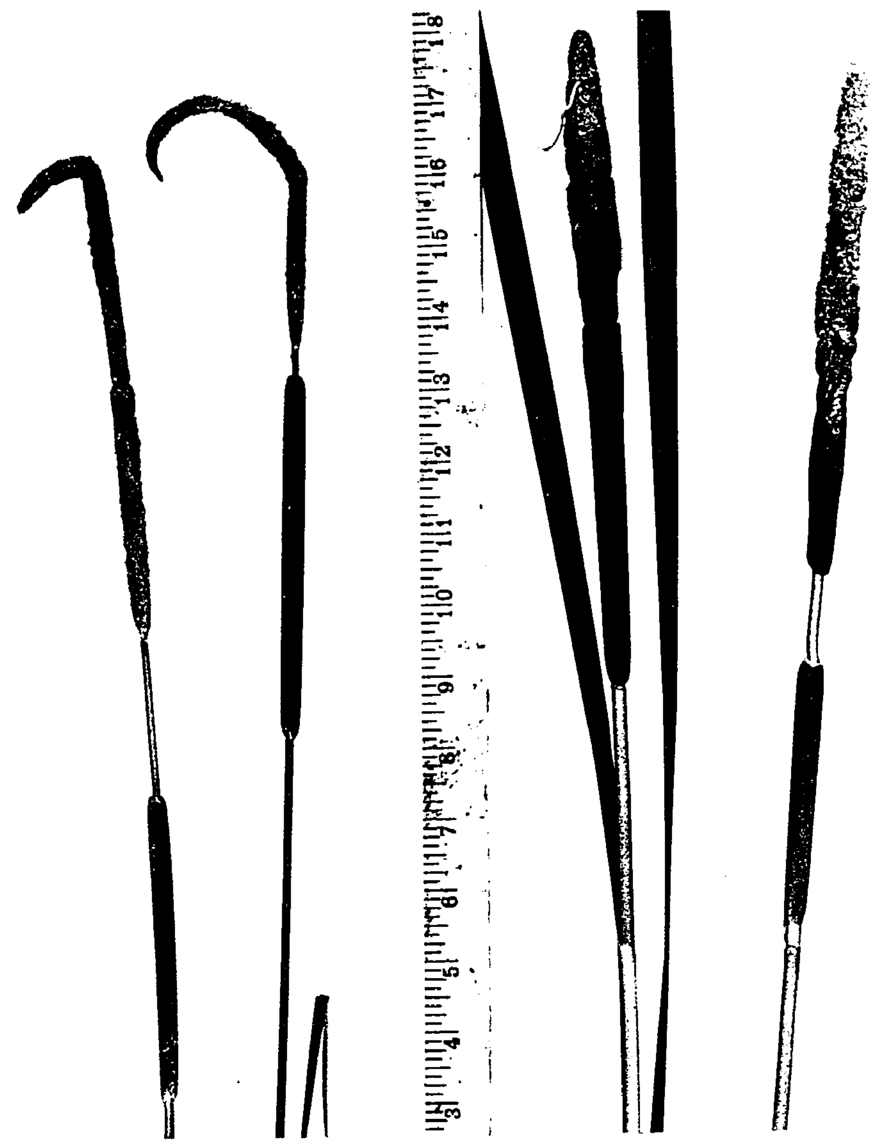
Nontreated	Treated
1-2 narrow-leaved cattail	6-7, 11-12, 16-17 narrow-leaved cattail
3-5 broad-leaved cattail	8-10, 13-15, 18-20 broad-leaved cattail

Plate III. Five weeks after cattail roots were immersed for 24 hours in 10 ppm of the phenoxyacetic acid formulation indicated.



Narrow-leaved cattail Broad-leaved cattail

Vegetative appearance



Narrow-leaved cattail Broad-leaved cattail

Fruiting bodies

Plate IV. Vegetative and fruiting appearance of broad- and narrow-leaved cattail plants.

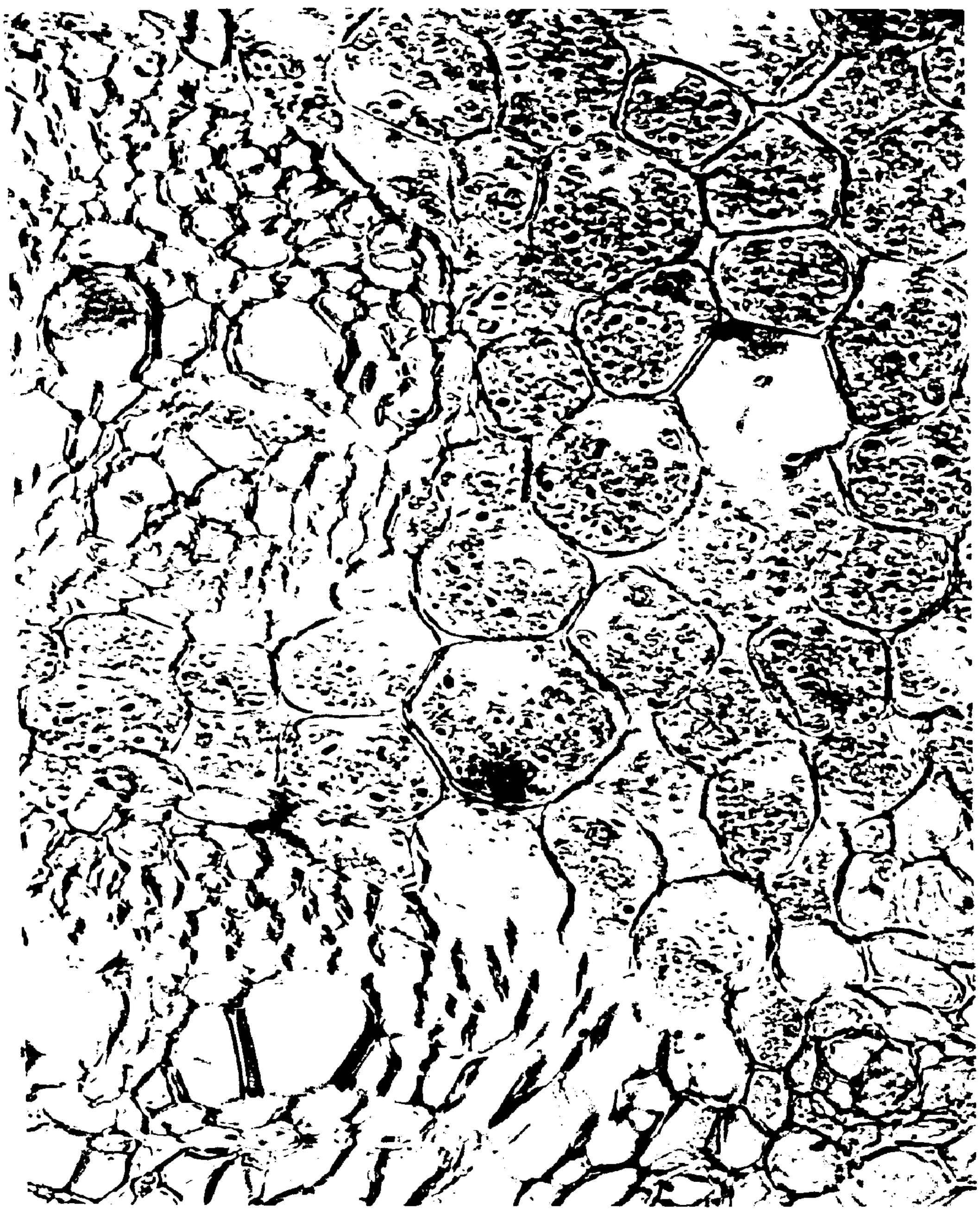


Plate V. Portion of narrow-leaved cattail rhizome cross section 500 X showing starch grains within cells.

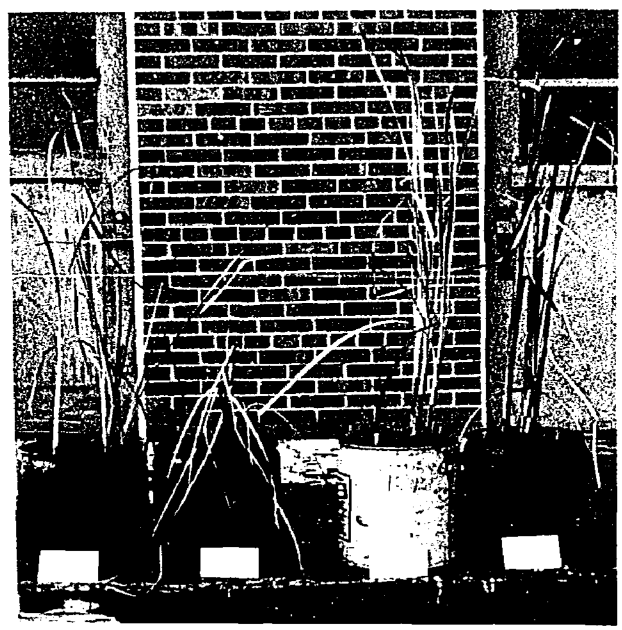
Plate VI. Cattail plants treated with systemic herbicidal formulations.

1056 1057 1006 1007

3 weeks after treatment

1066 1064 1016 1014

4 weeks after treatment



1066 1065 1016 1015

4 weeks after treatment

Nontreated

1056, 1066 narrow-leaved cattail
1006, 1016 broad-leaved cattail

Treatment--8-24-50

1064
12.65 lb 2,4-D, triethanolamine salt
10.56 lb 2,4-D, isopropyl ester

1014
15.71 lb 2,4-D, triethanolamine salt
13.11 lb 2,4-D, isopropyl ester

1065
3.92 lb 2,4-D, Na salt

1015
14.32 lb 2,4-D, Na salt

Treatment--7-7-50

1057
25.30 lb 2,4-D, Na salt

1007
41.46 lb 2,4-D, Na salt

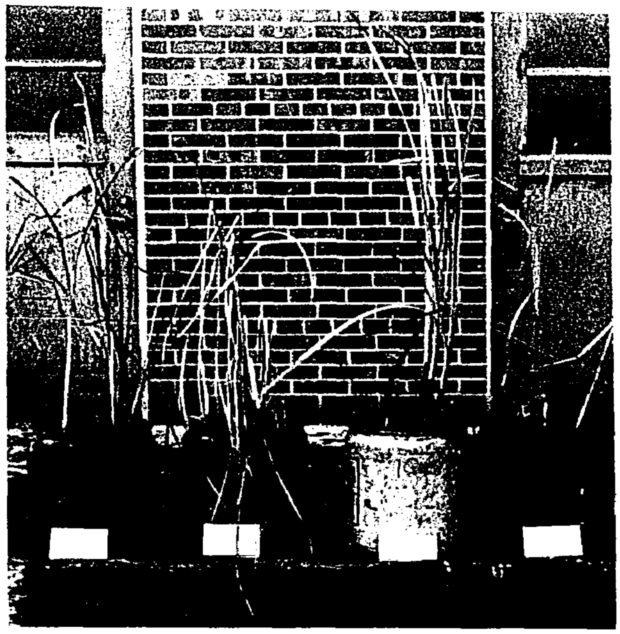


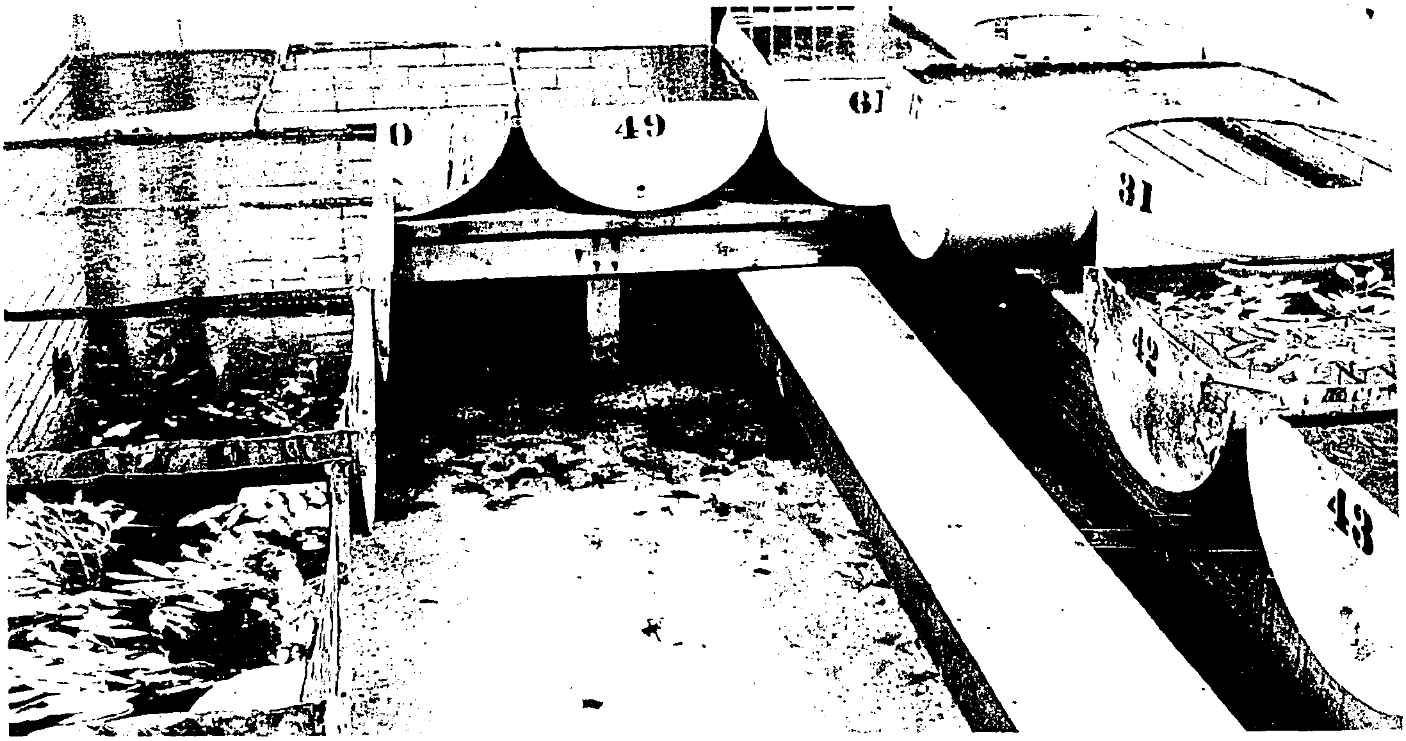
Plate VII. Cattail plants treated with systemic herbicidal formulations.

1066 1067 1016 1017 | 1066 1070 1016 1020

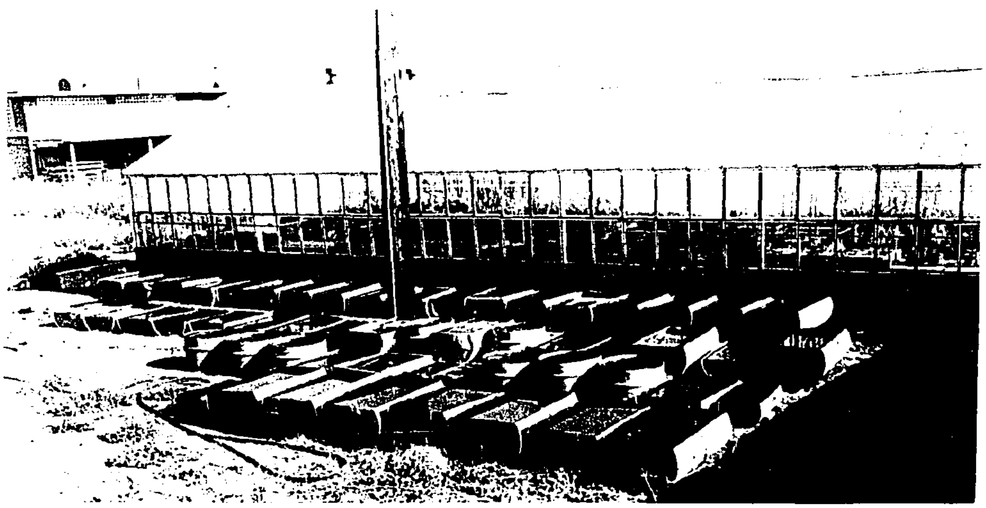
4 weeks after treatment | 4 weeks after treatment

Nontreated
1066 narrow-leaved cattail
1016 broad-leaved cattail

Treatment--8-24-50
1067
13.69 lb 2,4-D, Na salt
1017
17.55 lb 2,4-D, Na salt
1070
712.00 lb pentachlorophenol
1279.6 gal xylene
10.49 gal California Spray Ortho No. 5
1020
571.93 lb pentachlorophenol
1027.9 gal xylene
10.49 gal California Spray Ortho No. 5



A



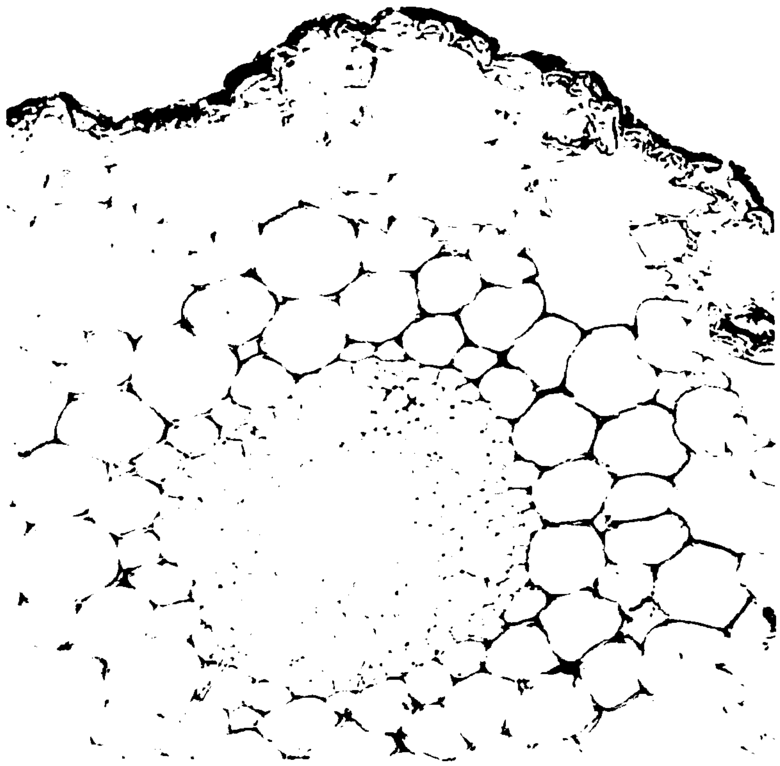
B

Plate VIII. Treatment room and culture area following treatment with the various chemical formulations.

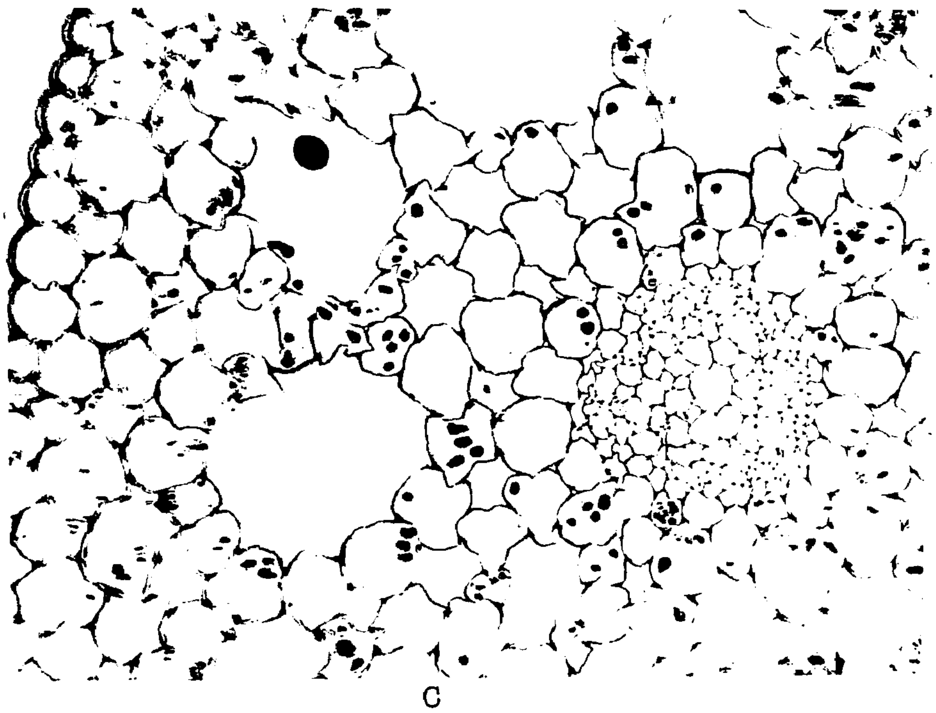
A. Phenoxyacetic acid treatment room

B. Tank cultures following treatment with phenoxyacetic acid and other chemical formulations

A



B



C

Plate IX. Portion of stem or rhizome cross sections of troublesome western waterweeds.

A. American pondweed rhizome 165 X

B. Leafy pondweed stem 330 X

C. True waterweed stem 165 X

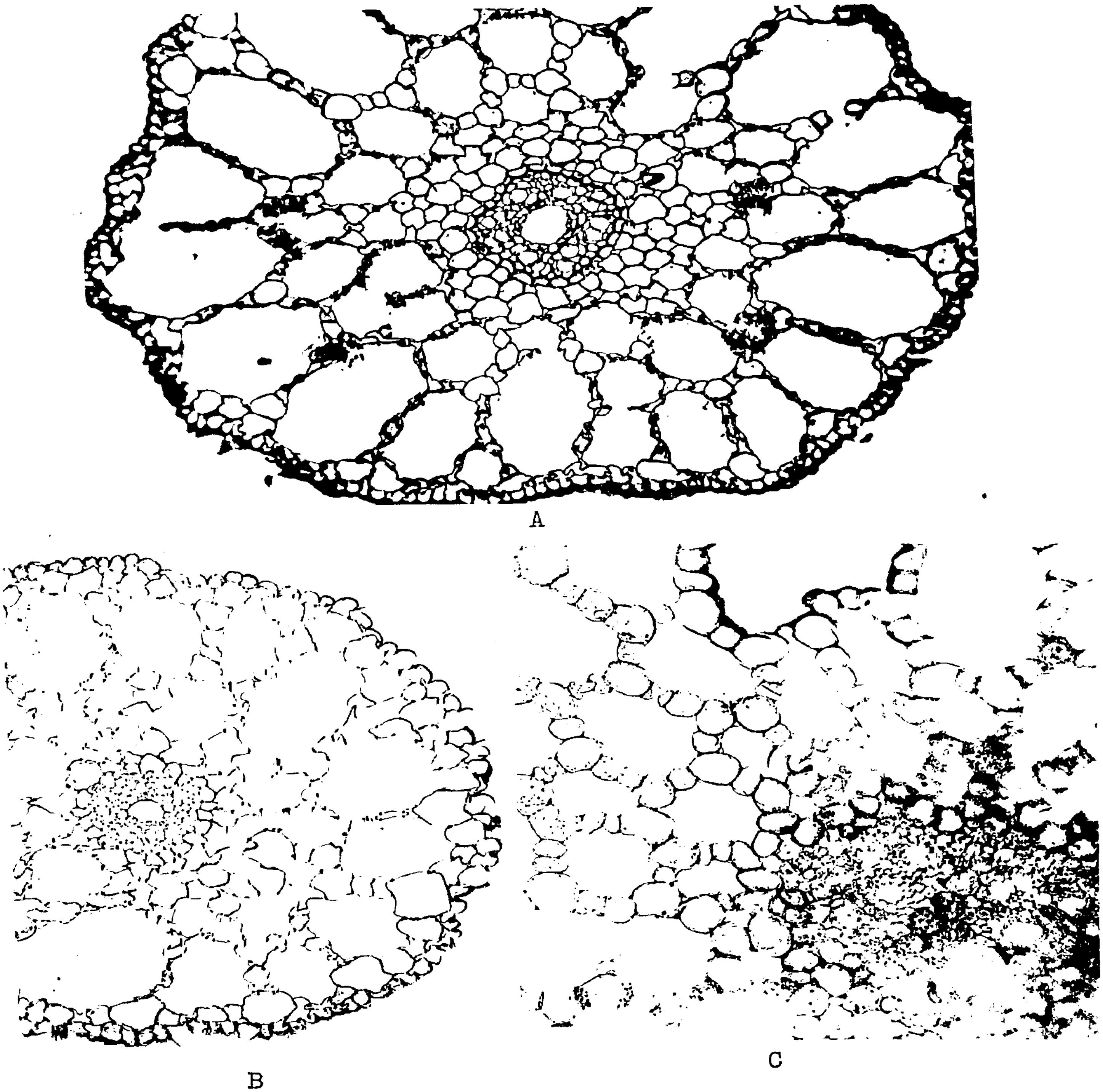


Plate X. Portion of stem or rhizome cross sections of troublesome western waterweeds.

A. Slender sago pondweed stem 165 X

B. Horned pondweed stem 165 X

C. Richardson's pondweed rhizome 165 X

A

B

Plate XI. Systemic herbicidal treatment on water sedge.

A. Water sedge
(*Carex aquatilis* Wahl.)
5 weeks after 1st treatment

B. 7 weeks after 2d treatment

Treatment 1--6-23-50
(Left tank--front)
27.20 lb 2,4-D, triethanolamine salt
Treatment 2--8-4-50
4.54 lb 2,4-D, triethanolamine salt
3.78 lb 2,4-D, isopropyl ester

Treatment 1--6-23-50
(Left tank--back)
30.29 lb 2,4,5-T, isopropyl ester
Treatment 2--8-4-50
14.39 lb 2,4,5-T, isopropyl ester

Comments
9-22-50

	2,4,5-T treated material			
Harvested	Living	%	Dead	%
plant analysis	19.2 g	21.1	71.6 g	78.9

2,4-D, salt, ester treated material			
Living	%	Dead	%
3.5 g	8.4	38.3 g	91.6

A

B C

Plate XII. Field photographs of three species of pondweed.

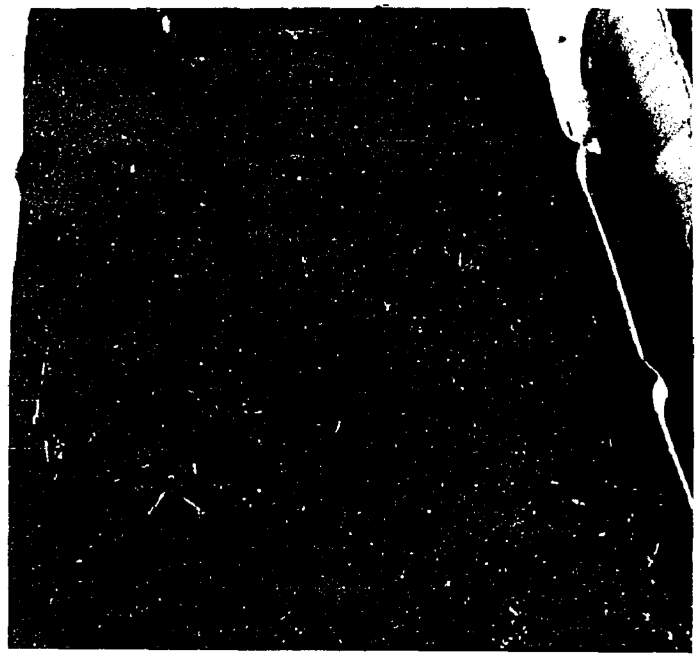
A. Leafy pondweed
(_Potamogeton foliosus_ Raf.)

B. Slender sago pondweed
(_Potamogeton pectinatus_ L.)

C. American pondweed
(_Potamogeton nodosus_ Poiret)

A

B



C

Plate XIII. Systemic herbicidal treatment on leafy pondweed.

Treatment 1--8-25-50
4.93 lb 2,4-D Na salt
Exposure: 3 hr 35 min

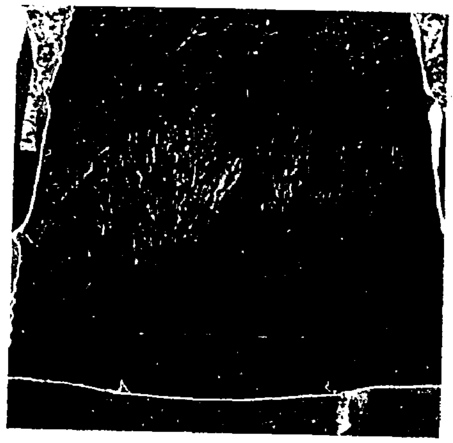
Comments 10-6-50
Estimated survival 0 %

A. Leafy pondweed
(*Potamogeton foliosus* Raf.)
Before treatment 8-24-50

B. 1 week after 1st treatment

C. 6 weeks after 1st treatment

A



B

C

Plate XIV. Systemic herbicidal treatment on leafy pondweed.

Treatment 1--8-25-50
5.65 lb 2,4-D, isopropyl ester
6.77 lb 2,4-D, triethanolamine salt
Exposure: 3 hr 45 min

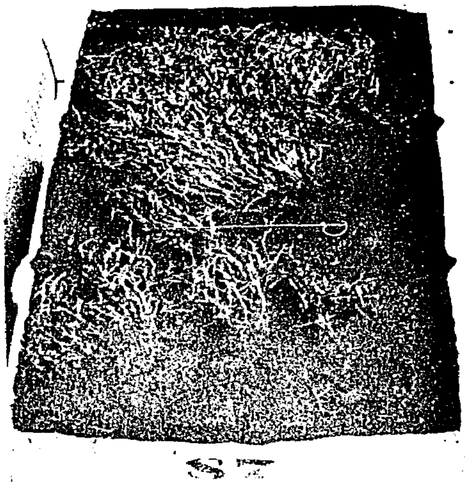
Comments 10-6-50
Estimated survival 5 %

A. Leafy pondweed
(*Potamogeton foliosus* Raf.)
Before treatment 8-24-50

B. 1 week after 1st treatment

C. 6 weeks after 1st treatment

A



B

C

Plate XV. Systemic herbicidal treatment on leafy pondweed.

Treatment 1--8-25-50
3.49 lb 2,4,5-T, isopropyl ester
Exposure: 6 hr 20 min

Comments 10-6-50
Estimated survival 85 %

A. Leafy pondweed
(*Potamogeton foliosus* Raf.)
Before treatment 8-24-50

B. 1 week after 1st treatment

C. 6 weeks after 1st treatment

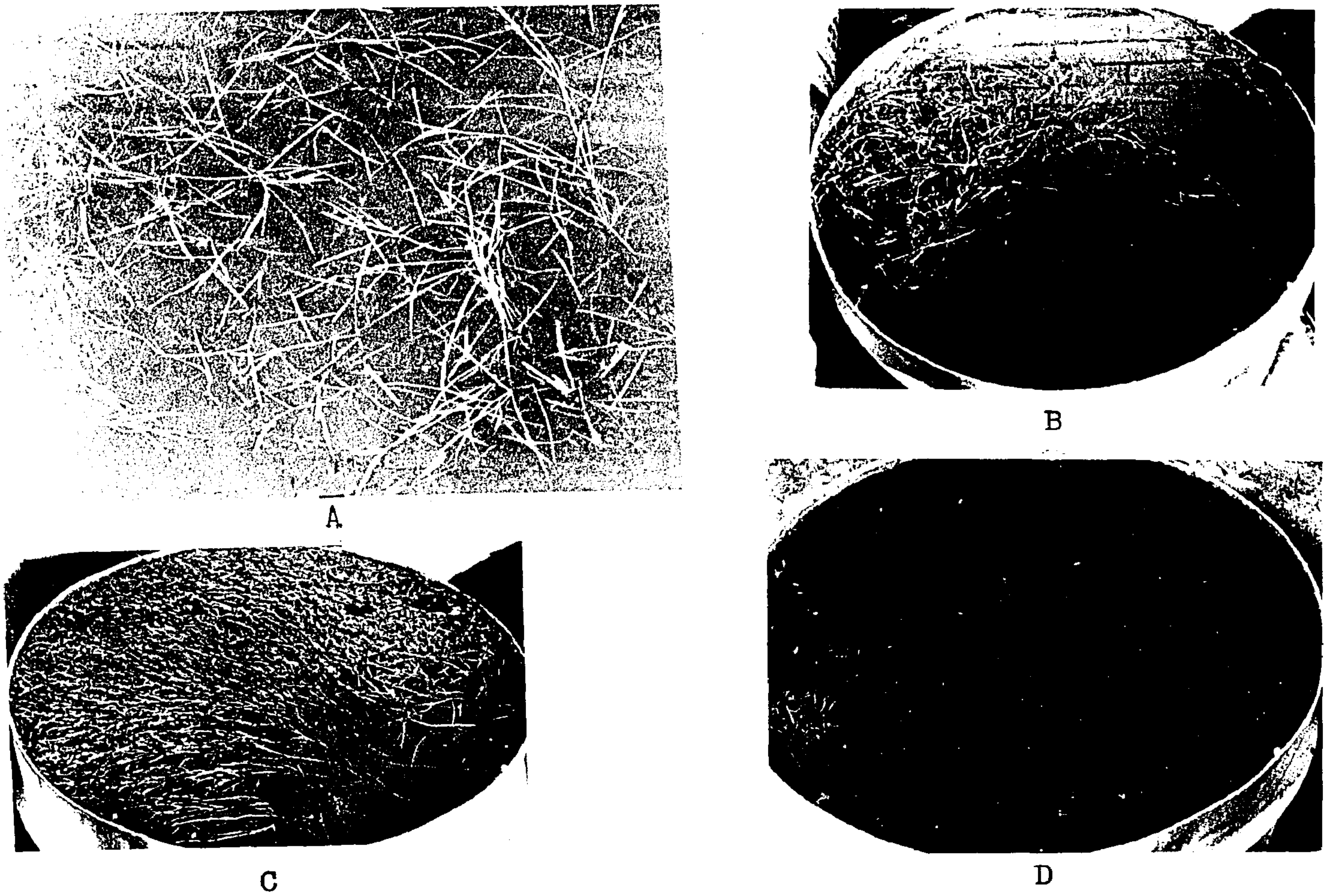


Plate XVI. Vegetative regrowth after cutting leafy pondweed.

<u>Treatment 1--7-7-50</u>
Proximal half of plants cut off at ground line with scissors
Exposure: 5 hr 30 min

<u>Treatment 2--8-7-50</u>
Plants in front half of tank cut off at ground line with scissors
Exposure: 4 hr 50 min
<u>Comments 9-29-50</u>
Estimated survival 100 %
Fresh weight 248.0g
Oven-dry weight 30.3
Percent oven-dry weight 12.2

A. Leafy pondweed (<u>Potamogeton</u> <u>foliosus</u> Raf.) Before treatment 7-7-50

B. 1 week after 1st treatment

C. 4 weeks after 1st treatment

D. 7 weeks after 2d treatment

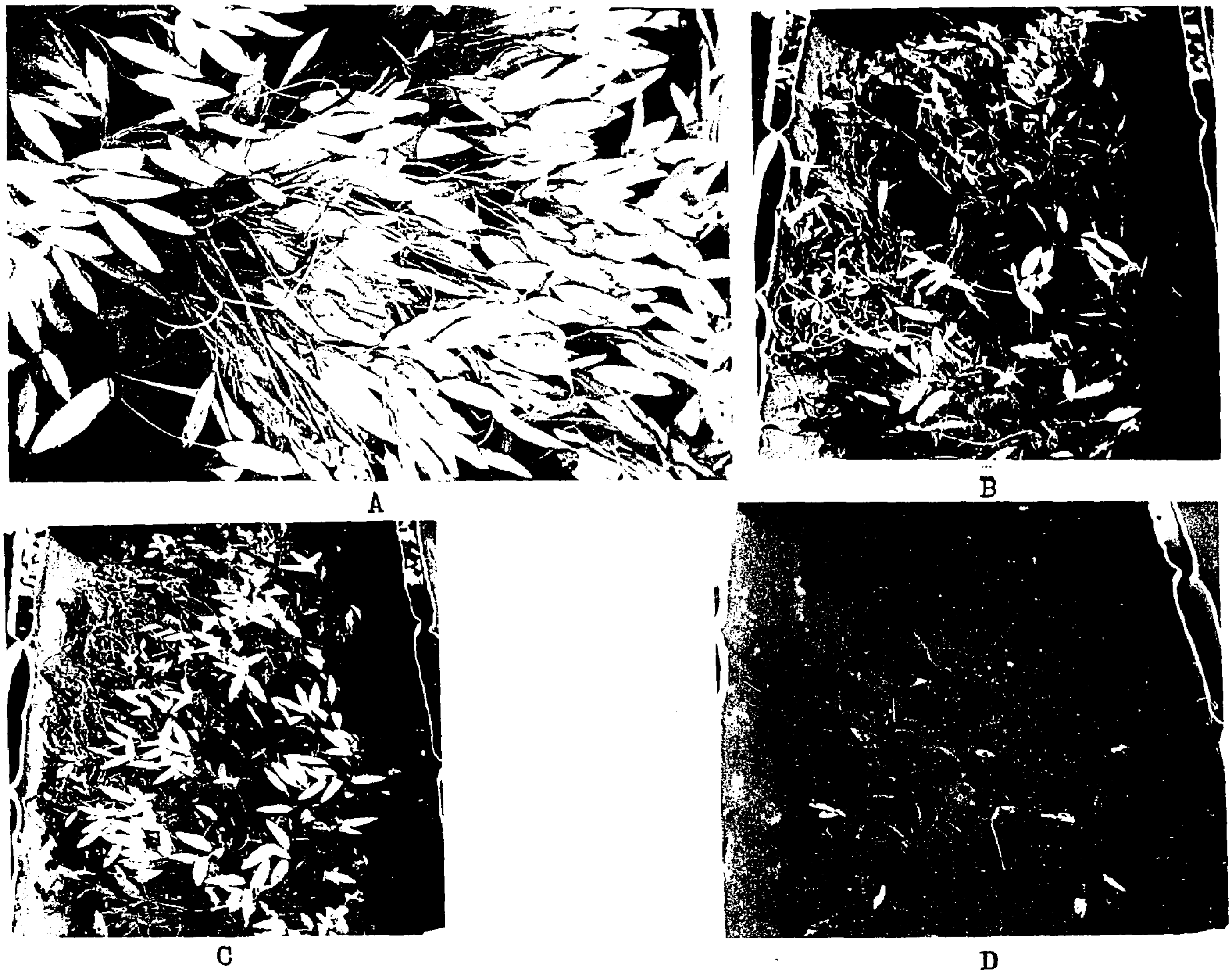


Plate XVII. Systemic herbicidal treatment on American pondweed.

Treatment 1--6-17-50
6.81 lb 2,4-D, triethanolamine salt
Exposure: 3 hr 45 min

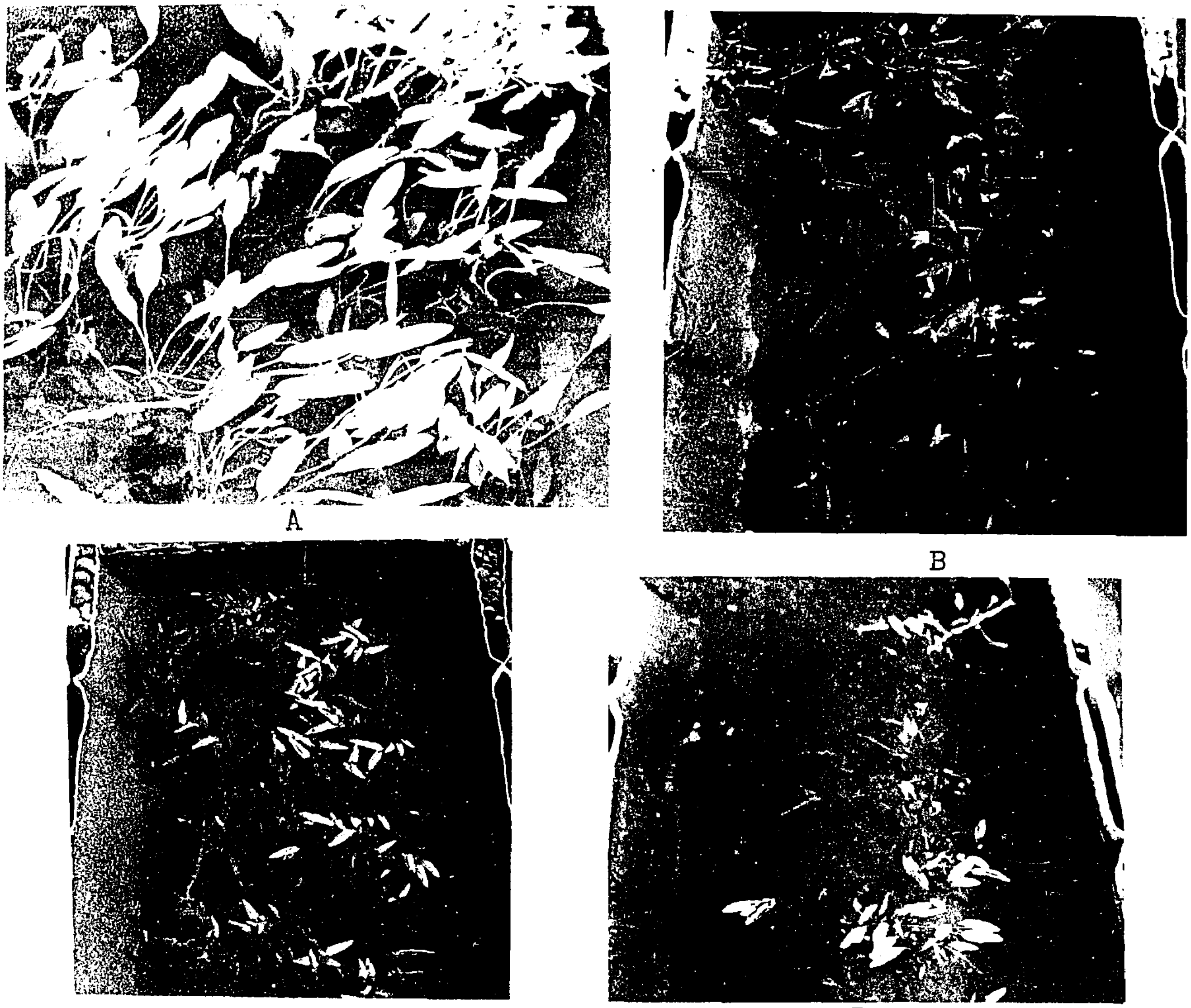
Treatment 2--8-4-50
6.81 lb 2,4-D, triethanolamine salt
Exposure: 3 hr 25 min
Comments 9-25-50
Estimated survival 2 %
Fresh weight 40.5
Oven-dry weight 3.7
Percent oven-dry weight 9.1

A. American pondweed (*Potamogeton nodosus* Poiret) Before treatment 6-15-50

B. 4 weeks after 1st treatment

C. 6 weeks after 1st treatment

D. 7 weeks after 2d treatment



A B C D

Plate XVIII. Systemic herbicidal treatment on American pondweed.

<u>Treatment 1--6-17-50</u>
5.88 lb 2,4-D, isopropyl ester
Exposure: 5 hr 10 min

<u>Treatment 2--8-4-50</u>
5.88 lb 2,4-D, isopropyl ester
Exposure: 3 hr 35 min
<u>Comments 9-25-50</u>
Estimated survival 5 %

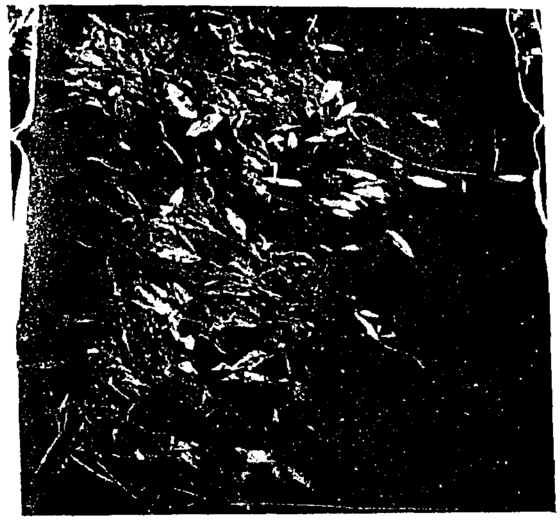
A. American pondweed
(*Potamogeton nodosus* Poiret)
Before treatment 6-15-50

B. 4 weeks after 1st treatment

C. 6 weeks after 1st treatment

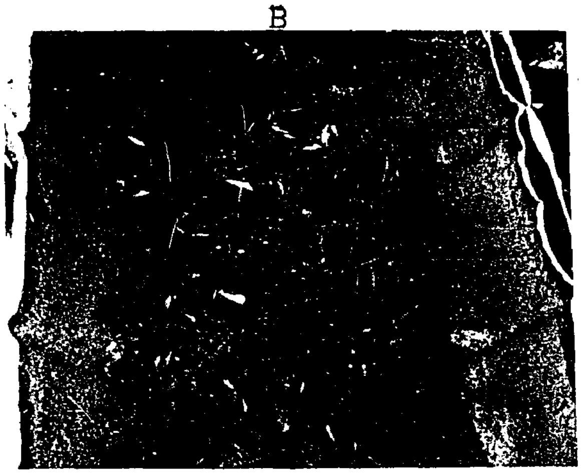
D. 7 weeks after 2d treatment

A



B

C



D

Plate XIX. Systemic herbicidal treatment on American pondweed.

<u>Treatment 1--6-17-50</u>
9.48 lb 2,4,5-T, isopropyl ester
Exposure: 3 hr 25 min

<u>Treatment 2--8-4-50</u>
7.32 lb 2,4,5-T, isopropyl ester
Exposure: 3 hr 15 min
<u>Comments 9-22-50</u>

Estimated survival	5 %
Fresh weight	53.7g
Oven-dry weight	3.6
Percent oven-dry weight	6.7

A. American pondweed
(*Potamogeton nodosus* Poiret)
Before treatment 6-15-50

B. 4 weeks after 1st treatment

C. 6 weeks after 1st treatment

D. 7 weeks after 2d treatment

B

A

C

D

Plate XX. Vegetative regrowth after cutting American pondweed.

Treatment 1--7-7-50
Plants in front half of tank cut
off at ground line with scissors
Exposure: 5 hr 45 min

Treatment 2--8-7-50
Plants in front half of tank cut
off at ground line with scissors
Exposure: 6 hr 20 min
Comments 9-29-50

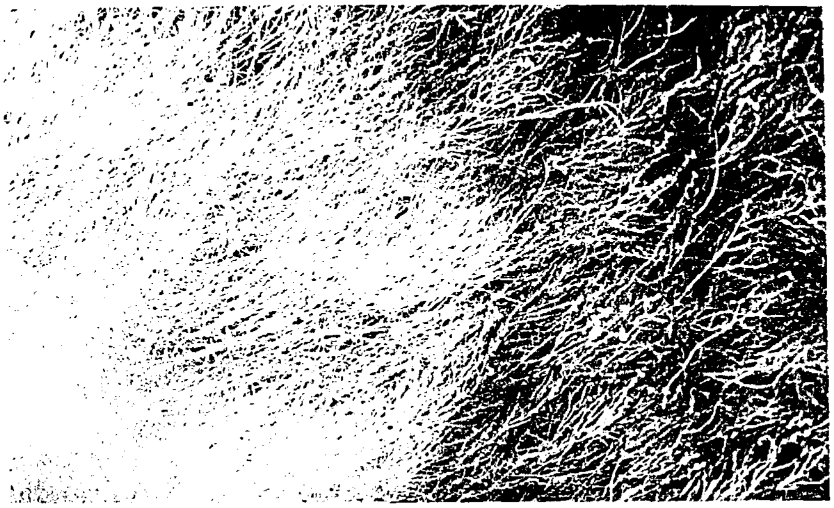
Estimated survival	100 %
Fresh weight	283.3g
Oven-dry weight	30.2
Percent oven-dry weight	10.7

A. American pondweed
(*Potamogeton nodosus* Poiret)
Before treatment 7-7-50

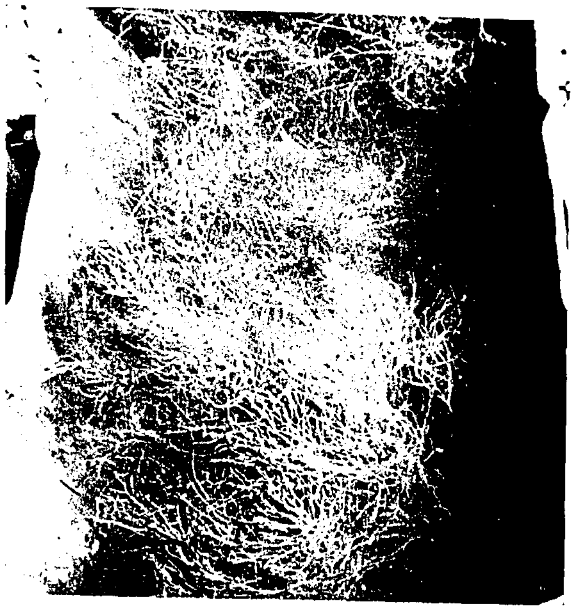
B. 1 week after 1st treatment

C. 4 weeks after 1st treatment

D. 7 weeks after 2d treatment



A



B

C

D

Plate XXI. Systemic herbicidal treatment on gigantic sago pondweed.

Treatment 1--6-17-50
6.81 lb 2,4-D, triethanolamine salt
Exposure: 4 hr 20 min

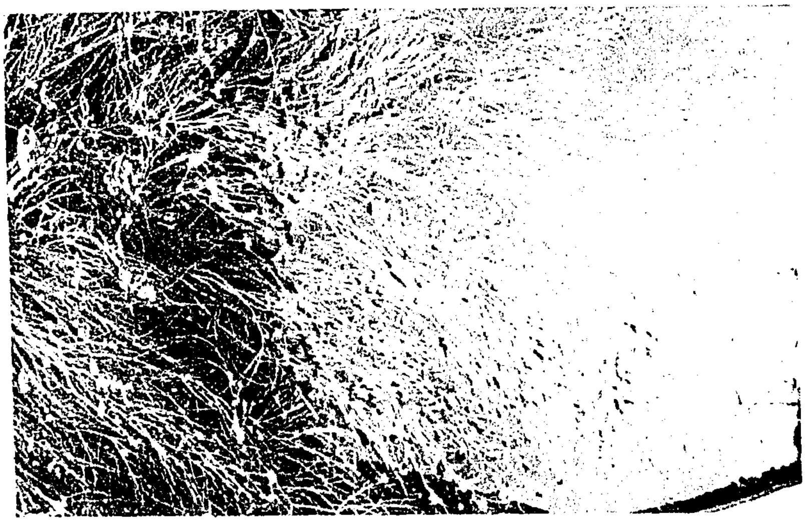
Treatment 2--8-4-50
4.54 lb 2,4-D, triethanolamine salt
Exposure: 3 hr 10 min
Comments 9-22-50
Estimated survival 2 %

A. Gigantic sago pondweed (*Potamogeton pectinatus* L.) Before treatment 6-15-50

B. 4 weeks after 1st treatment

C. 6 weeks after 1st treatment

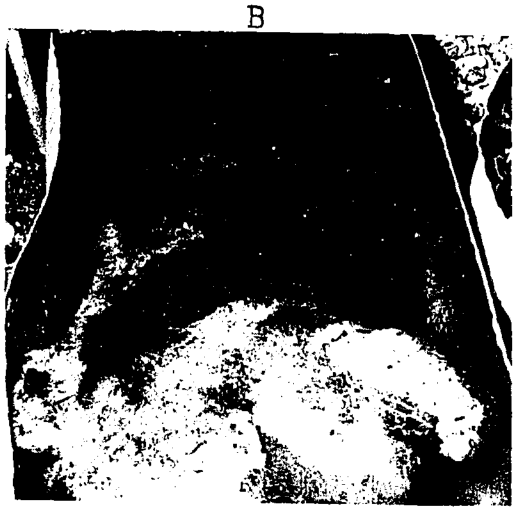
D. 7 weeks after 2d treatment



A

B

C



D

Plate XXII. Systemic herbicidal treatment on gigantic sago pondweed.

Treatment 1--6-17-50
5.88 lb 2,4-D, isopropyl ester
Exposure: 5 hr 40 min

Treatment 2--8-4-50
4.97 lb 2,4-D, isopropyl ester
Exposure: 3 hr 35 min
Comments 9-22-50
Estimated survival 1 %

A. Gigantic sago pondweed (*Potamogeton pectinatus* L.) Before treatment 6-15-50

B. 4 weeks after 1st treatment

C. 6 weeks after 1st treatment

D. 7 weeks after 2d treatment

A

B

C

Plate XXIII. Systemic herbicidal treatment on gigantic sago pondweed.

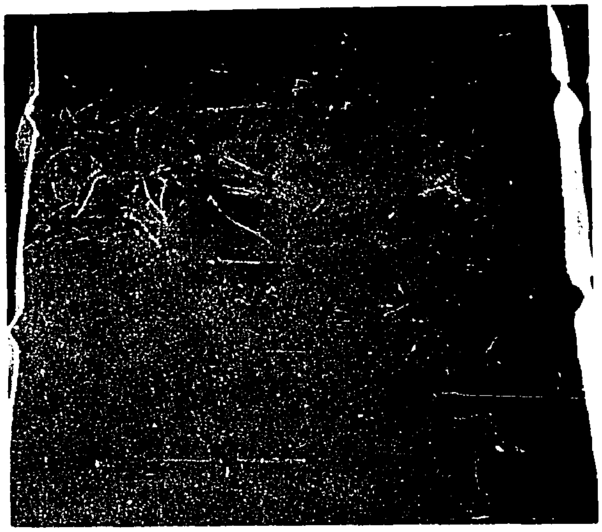
<u>Treatment 1--9-15-50</u>
10.62 lb 2,4,5-T, isopropyl ester
Exposure: 3 hr 50 min

<u>Comments 10-20-50</u>	
Estimated survival	20 %
Fresh weight	54.2g
Oven-dry weight	3.2
Percent oven-dry weight	5.9

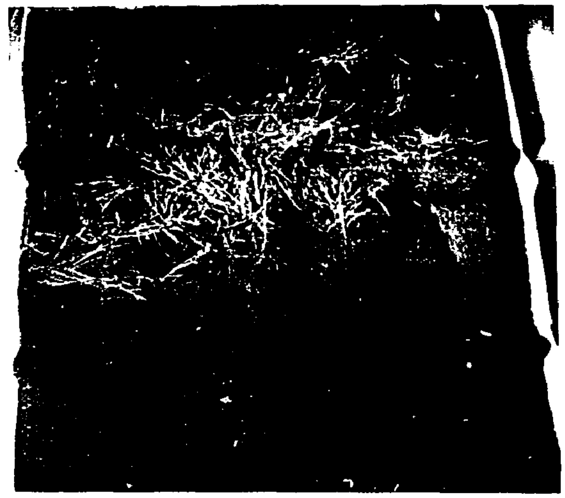
A. Gigantic sago pondweed (*Potamogeton pectinatus* L.) Before treatment 9-15-50

B. 3 weeks after 1st treatment

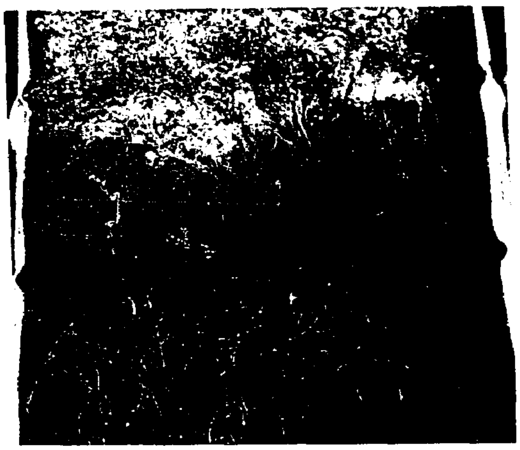
C. 5 weeks after 1st treatment



A



B



C

D

Plate XXIV. Vegetative regrowth after cutting gigantic sago pondweed.

<u>Treatment 1--7-14-50</u>
Plants in front half of tank cut off at ground line with scissors
Exposure: 5 hr 25 min

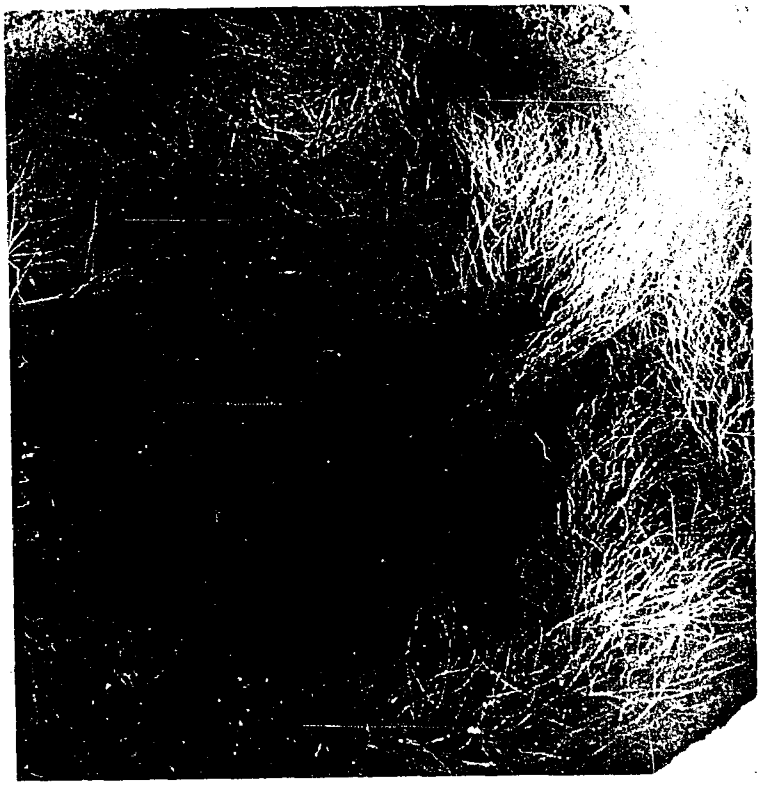
<u>Treatment 2--8-22-50</u>
Plants in front half of tank cut off at ground line with scissors
Exposure: 4 hr 55 min
<u>Comments 9-25-50</u>
Estimated survival 100 %

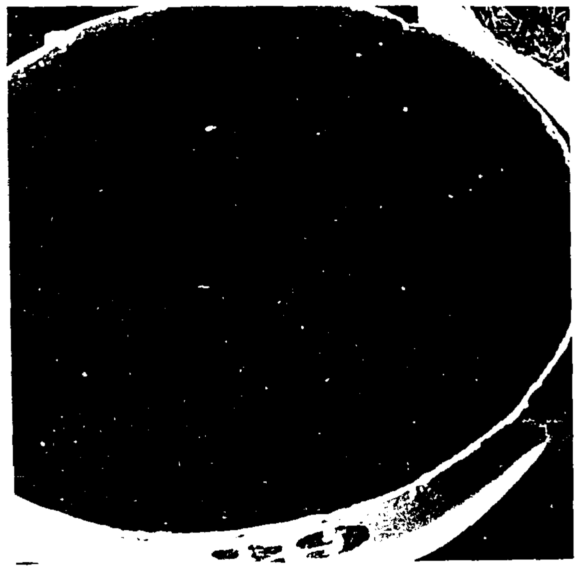
A. Gigantic sago pondweed (<u>Potamogeton</u> <u>pectinatus</u> L.) Before treatment 7-14-50

B. 2 weeks after 1st treatment

C. 6 weeks after 1st treatment

D. 4 weeks after 2d treatment





B

A

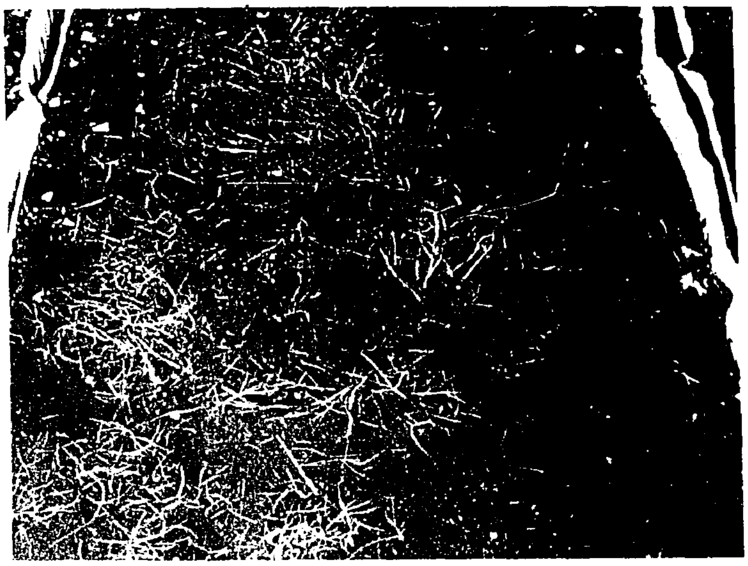
Plate XXV. Contact herbicidal treatment on slender sago pondweed.

Treatment 1--7-7-50
242.40 lb $NaAsO_2$
Exposure: 4 hr 35 min

Treatment 2--8-7-50
274.74 lb $NaAsO_2$
Exposure: 3 hr 35 min
Comments 9-29-50
Estimated survival 25 %
Fresh weight 9.2g
Oven-dry weight 0.5
Percent oven-dry weight 5.4

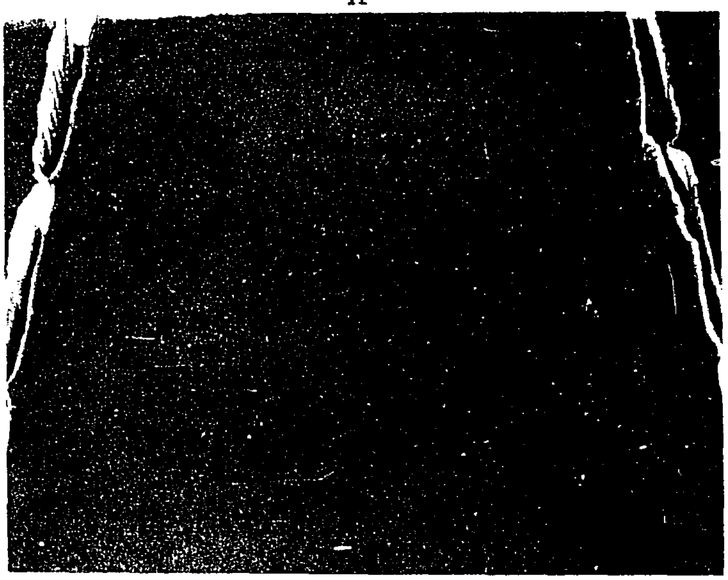
A. Slender sago pondweed (Potamogeton pectinatus L.) Before treatment 7-7-50

B. 7 weeks after 2d treatment



A

B



C

Plate XXVI. Systemic herbicidal treatment on horned pondweed.

Treatment 1--8-25-50
5.65 lb 2,4-D, isopropyl ester
6.77 lb 2,4-D, triethanolamine salt
Exposure: 3 hr 20 min

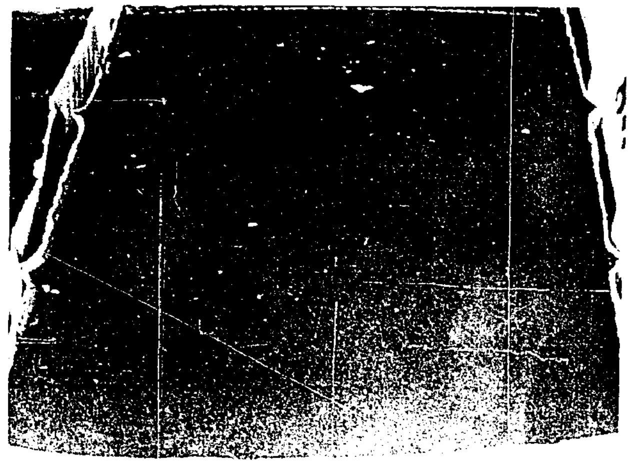
Comments 10-6-50
Estimated survival 0 %

A. Horned pondweed
(*Zannichellia palustris* L.)
Before treatment 8-24-50

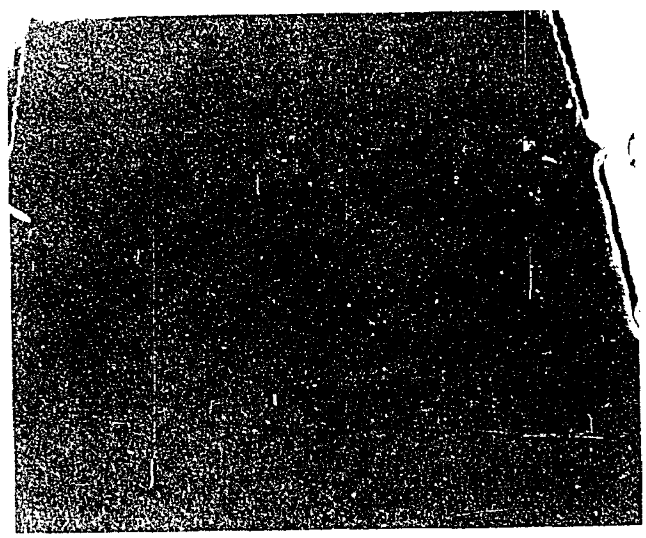
B. 1 week after 1st treatment

C. 6 weeks after 1st treatment

A



B



C

Plate XXVII. Systemic herbicidal treatment on horned pondweed.

Treatment 1--8-25-50
7.20 lb 2,4,5-T, isopropyl ester
Exposure: 5 hr 20 min

Comments 10-6-50
Estimated survival 0 %

A. Horned pondweed
(*Zannichellia palustris* L.)
Before treatment 8-24-50

B. 1 week after 1st treatment

C. 6 weeks after 1st treatment