AN ABSTRACT OF THE THESIS OF

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Title: THE BIOLOGY AND CONTROL OF REED CANARYGRASS (*PHALARIS ARUNDINACEA* L.) ON IRRIGATION DITCHBANKS

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Reed canarygrass (*Phalaris arundinacea* L.) is a desirable pasture grass on wet areas in the Northern United States and Southern Canada, but it is a serious and troublesome ditchbank weed in the Pacific Northwest and Rocky Mountain States. The purpose of this study was to learn more about the development, growth habits, and control of reed canarygrass on irrigation ditchbanks.

Ninety-seven percent or more of the seed of this species germinated immediately after harvest under favorable conditions. Seeds stored in damp sand at constant temperatures of 1 and 23C for periods of time up to one year did not germinate until they were subjected to alternating temperatures of 20 and 30C.

The first rhizome development on reed canarygrass seedlings grown in the greenhouse was observed 26 days after emergence. Within 16 weeks after emergence, the plants were in bloom and had 48 short rhizomes (6.5 cm maximum) per plant.

In the field, 88 percent or more of the emergent shoots on established plants originated from rhizome or tiller buds located in

the upper 5 cm of soil. Some shoots developed from buds located at depths up to 20 cm, but none arose from a greater depth.

Several vegetative characteristics of reed canarygrass plants collected from six irrigation projects in four states differed widely when grown in a garden at Prosser, Washington. The plant height, seed weights, panicle length, leaf length, leaf width, number of stems per plant, stem diameter, and the rate of spread by rhizomes were statistically different at the 5% level of probability. Large differences in the color and posture of the leaves were also observed. Plants collected near Huntley, Montana, were the most vigorous.

Total available carbohydrates in the roots and rhizomes of established reed canarygrass were not affected by single applications of 2,2,dichloropropionic acid (dalapon) at 22 kg/ha, 3-amino-s-triazole-ammonium thiocyanate (amitrole-T) at 4.5 kg/ha, or 1,1'-dimethyl-4,4'-bipyridinium ion (paraquat) at 1.1 kg/ha until 2 months after treatments were applied in May. By October, single applications of dalapon and amitrole-T and five repeated applications of paraquat reduced the carbohydrates 24, 28, and 50 percent, respectively. Two additional treatments of dalapon or amitrole-T or five additional treatments of paraquat in the second year of the study did not reduce the carbohydrate levels below those present during the first year.

Dalapon and trichloroacetic acid (TCA), applied to the soil or to the senescent foliage in November at rates from 22 to 88 kg/ha, provided good to excellent temporary control of reed canarygrass without denuding ditchbanks. Redtop (Agrostis alba L.) and reed canarygrass seedlings developed on the treated areas the following summer and reed canarygrass retained the dominant position unless the seedlings and plants that escaped the fall treatment were controlled with post-emergence applications of dalapon or amitrole-T. When the latter plants were controlled, redtop developed from natural or artificial seeding of the ditchbank and became the dominant species.

Maximum residue levels of TCA in irrigation water ranged from 104 to 225 ppb following fall applications of TCA at 82 kg/ha to both banks of three irrigation laterals that ranged from 4 to 14.5 kilometers long. Average residue levels at the downstream ends of the laterals during the first four hours that water flowed through them in the spring ranged from 34 to 47 ppb. Eight hours after the initial flow of water through laterals 4, 8.4, and 14.5 kilometers long, residue levels were less than 1 ppb in the two shortest laterals and only 2.7 ppb in the longest lateral. No residues were detectable in the water from any of the laterals after 48 hours.

The Biology and Control of Reed Canarygrass (Phalaris Arundinacea L.) on Irrigation Ditchbanks

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THE BIOLOGY AND CONTROL OF REED CANARYGRASS (*PHALARIS ARUNDINACEA* L.) ON IRRIGATION DITCHBANKS

INTRODUCTION

Reed canarygrass (*Phalaris arundinacea* L.) is a tall, coarse, rhizomatous, cool-season, perennial grass that is considered both a crop and a weed to agriculturists. Reed canarygrass was cultivated as a pasture and forage grass in Sweden as early as 1749, and shortly thereafter it was cultivated in the United States. Today it is grown for pasture, forage, ensilage, or seed in most of the Northern United States and in Southern Canada.

Because reed canarygrass forms a dense sod and is adapted to poorly drained soils, it also is used for erosion control along streambanks, gullies, ponds, and lakes. According to Heath (28), several public agencies advocated this practice two or three decades ago.

In about 1950, reed canarygrass was beginning to be recognized as a serious ditchbank weed on irrigation systems in the Pacific Northwest and Rocky Mountain states. Today, it is considered to be one of the two most troublesome weeds on irrigation systems in these regions. It grows vigorously along the waterline of ditches and to a lesser extent on the drier portions of the bank. Rootlets, that develop at each node in contact with water or moist soil, collect silt and result in the formation of a berm along either bank. The plant growth and soil deposit interfere with water movement to the extent that costly mechanical cleaning operations or frequent treatment with herbicides are required to maintain adequate water flow. Neither of these two general methods of control are acceptable or practical on many irrigation systems. Mechanical control, as well as most of the effective herbicides, render the ditchbank void of vegetation and subject to water erosion. Therefore, control of reed canarygrass by either method may create more problems than it solves. This is especially true on coarse textured soils and on sections of a channel that have a high water velocity.

A few studies have been conducted on the growth habit and biology of reed canarygrass. All of these were aimed at developing the grass for pasture and forage purposes. Information concerning the growth habit and carbohydrate status of this plant, when grown under aquatic conditions, may be useful in the development of a practical, economical, and effective method of management and control on ditchbanks.

Biological control of reed canarygrass by grazing is possible, but it is not practical on the thousands of miles of canals, ditches, and drains that traverse irrigation projects. In many sites where reed canarygrass is a problem, ditchbanks are too steep to permit grazing. Also, trampling at the waters' edge may cause severe erosion problems. Therefore, research on the control of reed canarygrass reported herein was confined to chemical methods only.

Development of efficacy data for a herbicide is only the beginning point in the development of that herbicide for a particular use. A host of other information is necessary to insure that the herbicide does not cause harmful side effects. The quantity of herbicide that leaches or otherwise gets into irrigation water is one of the important factors in the development of a chemical weed control program on ditchbanks. It is not only necessary to know the levels of contamination, but it is also mandatory to know the dissipation rate of the herbicide.

Objectives of the research reported herein were (a) to study some of the growth habits of reed canarygrass grown in an aquatic or semi-aquatic environment, (b) to determine the seasonal trend of carbohydrate reserves in the rhizomes and roots of reed canarygrass, (c) to develop an economical and practical method of controlling reed canarygrass without denuding the ditchbank, and (d) to determine the level of contamination and the dissipation rate of the most promising herbicide.

LITERATURE REVIEW

Description and Distribution of Reed Canarygrass

Reed canarygrass (Phalaris arundinacea L.) also known as herb mackaye, is a rhizomatous, perennial grass that is indigenous to the temperate regions of all five continents (28). The wide distribution of the species, the shipment of seed from one continent to another, and the efforts of plant breeders, have led to considerable variation within the species (5, 7, 17, 53).

Anderson made a detailed monographic study of the genus Phalaris in 1961 (1). An excellent description of Phalaris arundinacea L. by Anderson is as follows:

> Perennial from scaly, creeping rhizomes; culms 50-150 cm tall; leaves usually green, occasionally striped with white (in f. picta); panicle 7-40 cm long, spreading during anthesis; glumes 3.5-7.5 mm long, more or less equal, acute, usually wingless, when winged, the wing very narrow and inconspicuous, keel scarbrous; fertile floret 2.7-4.5 mm long, lanceolate, dull yellow when immature, gray-brown and shiny at maturity, nerves conspicuous, glabrous or with a few appressed scattered hairs; sterile florets 2,1-2.3 mm long; subulate, pubescent; grain 1.5-2.0 mm long, 0.7-1.0 mm wide; subovoid brown with faintly striate surface; somatic chromosome number 14, 27, 28, 29, 30, 31, 35, or 42, the chromosomes ca. 5.0 μ long at diakinesis.

The nonstriped population of Phalaris arundinacea L. with which this thesis is concerned, has been divided into ten infraspecific categories (1). These include varieties, subspecies, formae, and races. Most of the described infraspecific taxa were based upon vegetative characteristics such as the amount of branching, leaf coloration, and size, shape, and density of the inflorescence.

Roe and Mottershead (53) found a relationship between chromosome numbers and palatability in five reed canarygrass strains. Sheep, cattle, and rabbits preferred two strains with 28 chromosomes over two strains with 42 chromosomes. A single strain with 35 chromosomes was intermediate in palatability. Their data indicated that extracts from the unpalatable strains contained a distasteful substance. This was the only reference found that indicated rather large biochemical or physiological differences between strains.

Reed canarygrass is adapted to 37 of the states located within the continental limits of the United States (30). The largest acreages grown for agronomic purposes are in California, Oregon, Washington, Minnesota, Iowa, Wisconsin and Michigan (28). According to Schoth (55) most of the fields in the Pacific Coast region can be traced to a seeding made in the Coquille Valley of Coos County, Oregon, in about 1885. The original stand of the aforementioned seeding was still in existence in 1929.

Althouth the natural habitat of reed canarygrass is poorly-drained wet areas, it is one of the most drought-tolerant of the cool season grasses when grown on upland sites. Wilkins and Hughes (61) reported reed canarygrass to be more productive and drought resistant than six other pasture grasses, including meadow fescue (Festuca elatior L.). However, it is not adapted to alkali soils (55).

Several authors (4, 11, 44) reported that reed canarygrass could tolerate deep-ponded water for 35 to 49 days without causing excessive permanent injury. The plant age at the time of impoundment appeared to be related to the amount of injury sustained. Schoth (55) stated that moving overflow was not detrimental to reed canarygrass during either the dormant or active growth stage. However, deep-ponded water during the active growth stage usually resulted in the loss of many plants.

Reed canarygrass is extremely competitive. It will completely eliminate legumes from a community in 2 or 3 years (13,28). Frequently, a native plant that thrives well under a wide range of conditions and is so competitive that it excludes other plant species from a particular site is classified as a weed. However, only five references, four from the United States and one from the island of Mauritius, were found that dealt with reed canarygrass as a weed (16, 31, 32, 34, 52).

Conditions That Affect Seed Germination

Several authors reported that freshly-harvested mature reed canarygrass seed germinated readily when subjected to alternating temperatures of 20 and 30C, with illumination at the higher temperature (18, 25, 48). Usually, the germination percentage decreased with increasing periods of time in dry storage at room temperature. Vose (59) found a periodicity in the germination of seed stored for different periods of time at room temperature. Germination was highest immediately after harvest, declined during the winter, and by the next summer it was very poor. During the subsequent winter, germination rose to the immediate post-harvest level and declined again the second summer.

In studies with seven genotypes of reed canarygrass, Vose (59) reported that immediate post-harvest germination percentages ranged from 8.7 to 65.7. Removal of the palea from the caryopsis or mechanical injury to the palea enhanced germination. Also, the inhibitory effect subsided more readily under conditions of good aeration, and aqueous extracts of the caryopses did not inhibit the germination of lettuce seed. Vose therefore postulated that the intact palea limited the exchange of gases to the extent that the normal respiratory cycle failed to go to completion. Under such conditions, he believed an intermediate or side product accumulated in sufficient quantities to inhibit germination.

Colbry (18) conducted a thorough study on the effects of temperature on reed canarygrass seed germination. The optimum alternating temperature, from which the official test is based, was 20C for 16 hours and 30C with light for 8 hours. Constant temperatures were very unfavorable for germination. No more than 4 percent of the seed stored in a moist condition germinated at constant temperatures that ranged from 10 to 35C. However, when seeds exposed to these temperatures for 21 days were subjected to an alternating temperature of 20-30C, they germinated readily.

The effect of flooding on the germination and emergence of reed canarygrass has been thoroughly documented (1, 29, 43, 44). Seed of this species did not germinate when it was inundated with 2.5 to 15.2 cm of water for 63 days. Within 14 to 20 days after the water was removed, emergence commenced and it continued until total numbers of seedlings in all treatments and the control (not flooded) were similar. However, seedlings that were not flooded began to emerge 5 to 10 days after planting. These data indirectly corroborate Voses' hypothesis that dormancy was related to gas exchange within the air spaces of the grain.

Growth Habits of Reed Canarygrass

No information was found in the literature that dealt with the early development of reed canarygrass seedlings. Several authors (4, 22, 29) mentioned that seedlings began to emerge above the soil surface five to ten days after planting, but neither rate of root and shoot growth nor the growth stage at which rhizomes or tiller buds began to form was discussed.

Evans and Ely (22), working in Ohio with perennial plants, conducted the only comprehensive study of reed canarygrass growth habits that has been reported. They found that approximately 74 percent of the shoots developed from rhizomes and 26 percent developed from buds in the axils of basal leaves on above-ground shoots. New shoots developed in the largest numbers during the spring and autumn, whereas the majority of rhizomes developed during late spring and summer (21). Shoots that emerged during the spring and summer failed to survive the following winter, but those that emerged in the fall survived and produced new growth the next spring. Differences in winter survival of shoots were attributed to the location of the growing point at the time freezing temperatures occurred. The growing point of shoots that survived was located 9 mm to 3.2 cm below the soil surface, whereas, the growing point of shoots that succumbed was above the soil surface.

Two to five branch shoots developed from buds at the nodes of the primary shoot in late summer or during any time of the year if the grass was grazed or clipped (19, 20, 22). Unclipped plants that produced an inflorescence had 10 times as many branch shoots as plants that did not flower. The number of leaves per culm also ranged from about eight on those that produced an influorescence to 20 on shoots that did not produce an inflorescence. Once any portion of a leaf blade emerged from the sheath of older leaves, it did not contain any active meristematic tissue and partial defoliation did not stimulate renewed activity (9).

Reed canarygrass flowers in late May or early June in the northern United States. Once fertilization occurs, maturation of the seed is rapid. Bonin and Goplen (12) found that the seed disarticulated from the rachilla within 14 days after anthesis. Therefore, many of the seeds in the upper part of the inflorescence are released from the glumes before those near its base mature.

In their studies on the rhizomes of several grasses, Evans and Ely (21) found that reed canarygrass rhizomes which developed after mid-June did not produce leafy shoots until the following season. Conversely, rhizomes that were formed before the middle of June all terminated as above-ground shoots by the middle of August of that year. Rhizomes of quackgrass (Agropyron repens L.), redtop (Agrostis alba L.) and Kentucky bluegrass (Poa pratensis L.) did not behave in the same manner as reed canarygrass.

Also, the mode of branching in reed canarygrass rhizomes was distinctly different from the above mentioned grasses. Reed Canarygrass rhizomes did not branch to a large extent. Most rhizomes terminated in a single leafy shoot. New rhizomes then developed from buds at the nodes of the older rhizomes near the juncture with their terminal shoot and the sequence was repeated. The maximum depth that reed canarygrass rhizomes were found in the soil was 15.25 cm. The density of the roots and rhizomes of reed canarygrass is indicated in the work of Bennett and Doss (10). They reported that the underground portion of reed canarygrass weighed 13,470 kg/ha.

<u>Trend of Total Available Carbohydrate Reserves in Perennial Plants</u>

Many workers who have studied different carbohydrate fractions in underground parts of perennial weeds have concluded that the fractions added together as "readily available" carbohydrates (sugars+dextrin+ starch) (3,6,8,) or as total available carbohydrates (including substances hydrolyzable in mild acids (27, 33, 37, 40, 41, 54, 57) are one of the best measurements of a plant's response to seasonal conditions and to management or control practices.

Weinmann (60) states that acid hydrolysis of plant tissue removes some of the structural carbohydrates and that total available carbohydrate determinations based on such extracts results in high values. However, Smith, Paulsen, and Raguse (56) and Grotelueschen and Smith (26) have clearly shown that total available carbohydrate levels are very similar after hydrolysis with 0.2N H_2SO_4 or after takadiastase digestion. Both methods include the sugars, starch and fructosan in the final carbohydrate values.

The total available carbohydrates in underground storage organs of most perennial weeds studied under field conditions declined in early spring. Carbohydrates reached a low point at about the time the plants reached the bloom stage of development, even though this stage occurred at different times during the growing season. Most of the experimental data reported appeared to be in harmony with the generalization that new top-growth of plants in early spring or after cultivation or mowing is developed at the expense of previously accumulated organic reserves in the underground organs. Storage of carbohydrates in the underground portions of many plants was most rapid during the autumn. Frequently, carbohydrates constituted 35 to 60 percent of the total weight of rhizomes in October or November.

Several workers (6, 32, 37) reported a correlation between the percentage of total carbohydrates on a dry weight basis and the percentage of total dry matter in the underground parts of plants. This indicates that most of the changes in total solids occurred in the carbohydrate fraction.

Effect of Dalapon, Amitrole-T, and Paraquat on Total Available Carbohydrates in Rhizomes of Perennial Grasses

LeBaron and Fertig (38) found that 2,2-dichloropropionic acid (dalapon) had little effect on the carbohydrates in the rhizomes of quackgrass (*Agropyron repens*(L.) Beauv.) during the first 3 months after treatment. Thereafter, the carbohydrates decreased gradually until late summer and then they increased in the fall. McWhorter (45) reported that dalapon reduced the total carbohydrates in the rhizomes of johnsongrass (*Sorghum halepense* (L.) Pers.) by as much as 49 percent during the year of treatment. In May of the following year, the total carbohydrates had increased slightly and was at a level equivalent to 62 percent of the control plants. In these experiments, dalapon did not cause direct death of quackgrass rhizomes when not followed by tillage.

3-amino-*s*-triazole-ammonium thiocyanate (amitrole-T) reduced the carbohydrates in quackgrass rhizomes more rapidly than dalapon, but otherwise its action was similar to dalapon (38). Carbohydrate reserves reached a minimum in late summer and increased again in the fall. McWhorter and Porter (46) found that chlorotic tissue characteristic of amitrole injury metabolizes carbohydrates indirectly. They suggested that carbohydrates were converted to fats and then the fats were metabolized in respiration (46).

Turner (58) found that repeated application of 1, 1'-dimethyl-4, 4'bipyridiniumion (paraquat) reduced the carbohydrate reserves in the rhizomes of quackgrass to about 50 percent of the level obtained with an equal number of hand clippings. He suggested that paraquat translocated to the rhizomes and increased their respiratory rate at the expense of stored carbohydrates. Funderburk and Lawrence (24) have shown that paraquat stimulates respiration in Lemna spp. and Mees (47) found that 6, 7-dihydrodipyrido [1,2-a:2',1'c] pyrazinediium ion (diquat) increased oxygen uptake by bean roots. Putnam and Ries (50) found that paraquat moved primarily in an acropetal direction in quackgrass, but some of the herbicide also moved several cm in a basipetal direction.

Control of Reed Canarygrass

Reed canarygrass is easily killed by fall plowing (4), or by plowing and disking (61). However, control by such methods is not possible on the majority of the irrigation ditchbanks in the Western United States. Most ditchbanks are too steep and/or rocky to permit any type of conventional equipment to traverse them.

Early work with soil sterilant type herbicides indicated the relative ineffectiveness and disadvantages of such herbicides for control of reed canarygrass on ditchbanks. In Utah, 3-(p-chlorophenyl)-1,1-dimethylurea (monuron) at 134 kg/ha reduced the stand of reed canarygrass 90 percent during the year after treatment, but the denuded banks cracked and toppled into the canal (32). At rates of 101 kg/ha or less, monuron did not reduce the stand of reed canarygrass more than 65 percent. Likewise, sodium chlorate at rates up to 1,075 kg/ha was ineffective for the control of reed canarygrass along the waterline. Hodgson (31) also found that 5-bromo-3-sec-butyl-6-methyluracil (bromacil), 2-chloro-4 (ethylamino)-6-(isopropyl-amino)-s triazine (atrazine), and 2,4-bis (isopropylamino)-6- methoxy-s-triazine (prometone) did not provide adequate control of reed canarygrass at rates up to 22 kg/ha.

Rochecouste (52) and Hodgson (31) found that late fall application of trichloroacetic acid (TCA) effectively controlled or suppressed reed canarygrass for various periods of time. The length of time that a single application was effective was dependent upon the rate of application. Rates of 45 to 90 kg/ha were required to maintain adequate control for one growing season, and rates as high as 224 kg/ha did not eliminate the grass.

Dalapon and amitrole-T were the most effective and consistent foliar-applied herbicides evaluated for the control of reed canarygrass on ditchbanks in Montana, Idaho, Washington, and Wyoming (16, 31, 34). However, two or three applications of either herbicide were required each season to maintain adequate control along the water's edge. Rates of dalapon and amitrole-T needed to provide such control were about 22 and 5.6 kg/ha, respectively.

TCA Residues and Rate of Dissipation in Irrigation Water

No specific references were found that pertained to the quantity of TCA that may be found in irrigation or runoff water following fall applications of the herbicide for weed control. However, data concerned with the movement and persistence of TCA in soils indicates that little, if any, TCA would be expected to enter irrigation water following applications in the fall after water is turned out of the channels.

Ogle and Warren (49) found that 10 cm of water applied to the surface of soil columns leached 95 to 100 percent of the biologically active TCA from the soil surface. Results were similar with fine sandy, silt loam, or muck soils that contained 1.0, 3.5, and 81.0 percent organic matter, respectively. Moreover, Leopold and van Schaik (39) showed that only 13 percent of a 10^{-4} molar solution of TCA was adsorbed by a charcoal slurry that contained 400 mg of charcoal per liter.

Loustalot and Ferrer (42) also determined that TCA was extremely mobile in the soil and that it decomposed readily in moist, warm soils. Decomposition, as measured by a decrease in phytotoxicity, was much greater at temperatures above 20C than at 10C. TCA applied at 34 kg/ha to moist soil that was maintained at 20C to 30C was nearly completely decomposed within 1 month. When the storage temperature was elevated to 45C, only 2 weeks were required to bring about the same degree of decomposition. Conversely, very little, if any, of the applied TCA was decomposed after storage at 10C for 2 months. These data suggest that soil microflora are important for the breakdown of TCA in the soil. Jensen (35) found that a specialized group of bacteria, possibly Arthrobacter, were responsible for the decomposition of TCA in the soil.

EFFECT OF STORAGE CONDITIONS ON THE GERMINATION OF REED CANARYGRASS SEED

Introduction

Sixty-eight to 90 percent germination has been reported for reed canarygrass seed immediately after harvest (25,59). In the Yakima Valley of Washington, seed is dehisced in late June and early July. Even though temperature and moisture conditions are nearly ideal for germination at this time of the year, and again in September, many of the seeds apparently do not germinate until late February or early March of the following year. These seedlings were one of the main obstacles in the development of a satisfactory control and revegetation program.

Therefore, the following study was conducted to determine the germination of seed produced in the Yakima Valley immediately after harvest and to determine the effect of certain storage conditions on germinability.

Materials and Methods

Seed was collected from an infestation of reed canarygrass located on the banks of the Roza Canal near Sunnyside, Washington, on June 21, 1968. A large flat pan was placed beneath each panicle and the panicle was tapped lightly to insure that only mature seed would be collected. The seed was mixed thoroughly and 438 samples of 100 seeds each were removed for the study.

Six of the 100-seed samples were subjected to germination tests immediately after harvest. The remainder was divided into groups of 72 for storage in damp sand or for dry storage at the following temperatures: (1) room temperature (ca.23C), (2) air temperature (alternating temperature), or (3) 1C. Samples stored in damp sand were placed in nylon mesh bags prior to burial in a plastic bin. The sand was watered periodically to maintain it in a damp condition. Dry-stored seeds were placed in test tubes that were covered with nylon mesh screen. The test tubes and plastic bin that contained the seed to be stored at air temperature were enclosed in a large wooden box to insure their safety, and to prevent precipitation from contacting the dry-stored seeds. The box was located on the north side of a building. The mean daily maximum and minimum air temperatures ranged from 32C to -3C, and from 12.6C to -10C, respectively, during the course of the study.

Each month, for a period of 1 year, six random samples were removed from each treatment and subjected to germination tests under standard conditions (2). Petri dishes used for the germination tests were arranged in a randomized block design within a germination chamber.

Results and Discussion

Germination of seed immediately after harvest averaged 99 percent (Figure 1). A similar lot of seed was collected in 1969, and 98 percent of this seed also germinated immediately after harvest. These results indicated that seed produced along a canal, where soil moisture is always plentiful, would probably germinate within 2 to 3 weeks after it was dihisced.

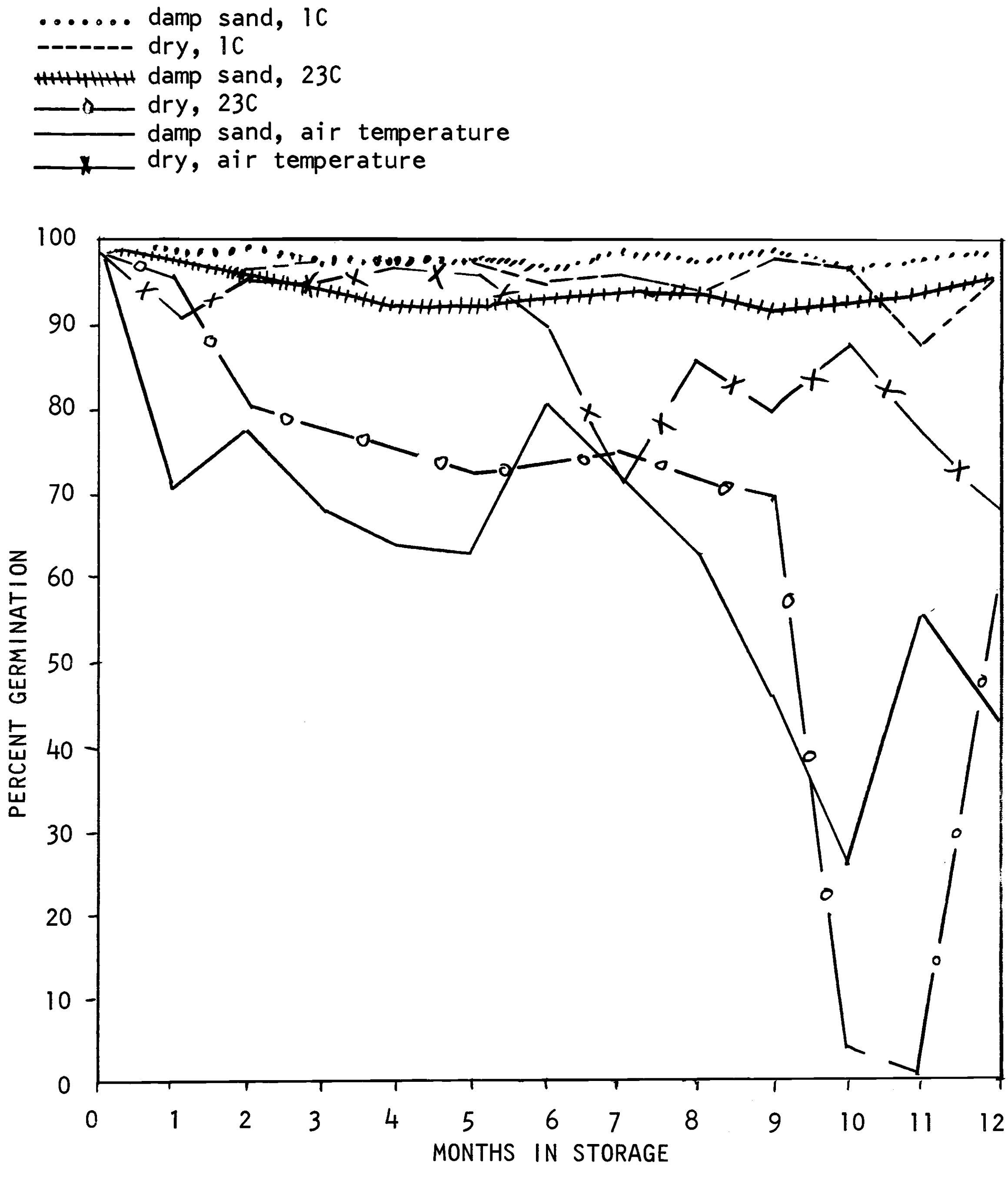

FIGURE 1. The effect of six storage conditions on the germination of reed canarygrass seed.

The germination of seed stored dry or in wet sand at 1C, and of those stored in wet sand at room temperature, remained extremely high throughout the 12-month period. After 12 months in storage, 92 to 99 percent of the seed stored under such conditions germinated. Colbry (18) reported that reed canarygrass seed maintained in a moist condition at constant temperatures that ranged from 10 to 35C did not germinate during a 21 day period. However, upon removal to an alternating temperature of 20 to 30C, the seeds germinated readily. Although storage conditions in Colbrys' and these studies may not be directly comparable, the inhibition or lack of seed germination at a constant temperature seems to be confirmed.

The germination of seed stored in a dry condition at room temperature (ca.23C) decreased rapidly between the first and second months of storage and again between the ninth and tenth months of storage (Figure 1). However, germination then increased from one percent after 11 months of storage to 59 percent after 12 months. Apparently, storage under such temperature conditions caused the induction of a secondary dormancy. Vose (59) obtained similar results for reed canarygrass seed stored at room temperature, with the exception that the secondary dormancy was broken more rapidly in this study.

More than 90 percent of the seeds removed from dry storage at air temperature germinated each month during the first 6 months of the study. Germination decreased to 71 percent during the seventh month and then it fluctuated between 88 and 69 percent during the last 5 months of the experiment. The relative humidity was usually higher in the box where the seeds were stored dry at air temperature than in the building where they were stored at room temperature. It seems reasonable to assume that the rate of respiration would have been greater in those seeds stored at the higher relative humidity and that seeds stored under such conditions would lose viability more readily than seeds stored at the lower relative humidity. At least, this should have been true during the first three months of the study when the mean daily maximum air temperature was 28.2C.

Data on the germination of seeds stored in damp sand at air temperature were not reliable because some of the seeds germinated in storage. However, a significant number of seeds stored under such conditions did not germinate until they were removed from storage and subjected to germination tests (Figure 1). Ample seed remained viable at the end of each month to allow establishment of a troublesome population of reed canarygrass on irrigation ditchbanks.

DEVELOPMENT OF REED CANARYGRASS SEEDLINGS

Introduction

Seedling plants of most rhizomatous perennial grasses are usually relatively easy to kill up to the time that rhizomes begin to form. After rhizomes form, they become increasingly difficult to destroy because regeneration occurs from each node along the rhizome as well as from the central crown. Because the germination and emergence of reed canarygrass seedlings on ditchbanks are extremely variable, it is imperative to know the growth stage at which rhizomes begin to form. If possible, it would be advantageous to aim a seedling control program at the latest possible date in order to destroy the late-emerging seedlings. Also, a knowledge of the growth rate and development of the seedlings may contribute to a better understanding of this species.

Methods and Materials

Two studies were conducted in the greenhouse to observe the growth and development of seedlings. In one of the studies, plants were grown in containers, hereafter called root boxes, that permitted periodic observation of the roots and rhizomes without destroying or disrupting the plants. In the other study, plants grown in fiber pots were dug up at 2-week intervals to observe the roots and rhizomes. Three plants from the latter study were selected at random on each of the sampling dates.

Three reed canarygrass seeds were planted in the center of two root boxes or in the center of 25 cm diameter pots. As soon as the seedlings became established, they were thinned to one per pot or root box and maintained in the greenhouse under favorable growing conditions. A photoperiod of 12 hours and alternating temperatures of approximately 25C in the daytime and 16C at night were maintained.

Root boxes were constructed of galvanized metal and glass. Metal was used for three sides and the bottom of the root box and a double strength pane of glass constituted the fourth side of the box. A metal cover was fitted over the glass to prevent light from reaching the underground portion of the plant. The root boxes were maintained at an angle of about 30 degrees from a vertical position so that the bulk of the roots and rhizomes would intercept the glass. Removal of the metal cover permitted observation of the undergound organs. Dimensions of the root box were 30 cm wide, 12 cm thick and 68 cm deep.

Results and Discussion

Seedlings began to emerge 9 days after planting and the first rhizome was observed 26 days later. At the time that rhizome initiation occurred, the plants had four shoots with a maximum of six leaves per shoot. Plant height averaged 21.5 cm and roots were visible in the root box to a depth of 28.5 cm (Table 1).

Additional rhizomes developed slowly until the plants were 8 to 10 weeks old, and then they developed rapidly during the next 2 to 4 weeks. The number of rhizomes visible in the root box increased from seven at 9 weeks of age to 22 at 10 weeks of age. Likewise, rhizomes on plants harvested from the fiber pots increased in numbers from 17.3 to 40.8 during the 2-week period between 10 and 12 weeks of age.

TABLE 1. The vegetative development of reed canarygrass seedlings grown in glass-fronted root boxes.

Plant Age weeks 1/	Leaves				Plant Height (cm)	Root Length (cm)	Rhizomes	
	No. of Shoots	No. per Shoot	Length (cm)	Width (mm)			No.	Max. Length (cm)
2	1.0	0	-	1	6.1	3.6	0	
3	1.0	3	9	1	8.3	12.2	0	
4	1.0	5	16	5	13.5	21.0	0	
5	4.0	6	23	9	21.5	28.5	1	1.0
6	5.5	6	27	11	25.0	43.0	1	1.5
7	8.5	7	27	13	41.8	53.5	4	3.2
8	23.5	7	32	16	44.0	61.0	6	5.5
9	26.0	8	33	17	46.5	65.0	7	6.5
10	34.5	10	34	17	47.0	66.0	16	6.5
11	36.5	10	34	17	49.0	66.0	22	6.5
12	44.5	10	34	17	53.5	66.0	24	6.5
14	51.5	10	34	18	59.5	66.0	27	6.5
16	58.0	10	34	18	84.5	66.0	27	6.5

1/Plant age is based on the planting date; emergence of seedlings required nine days.

Thereafter, rhizome development was slower and after 16 weeks there were 27 and 48 rhizomes on plants grown in the root boxes and fiber pots, respectively. Of course, only approximately one-half of the rhizomes present on the plants grown in root boxes were visible. The new rhizomes grew in an arc from the base of the plant to a depth of 2 to 5 cm and then they turned upward to form a new shoot (Figure 2). The maximum length of any rhizome observed in the study was 6.5 cm. Roots penetrated to a depth of 60 cm (the bottom of the root box) 10 weeks after the seed was planted.

Thirteen weeks after emergence the plants began to flower and they were in full bloom 2 weeks later (Figure 3). Thus reed canarygrass grown in the greenhouse under the described conditions completed a life cycle in approximately 4 months.

Environmental conditions in the greehouse were ideal for the rapid growth of reed canarygrass and plants grown under field condition would not necessarily develop as rapidly. Observations in the field indicated that 18 to 20 weeks were required for a seedling to complete a life cycle.

These results indicate that it would be highly unlikely that most irrigation projects could control reed canarygrass seedlings on their entire systems before rhizomes developed. Uneven emergence of seedlings due to differences in seed burial depth and soil temperatures, coupled with the length of time required to treat several hundreds of miles of ditchbanks would prevent such treatments before some of the seedlings that emerged early in the season developed rhizomes.

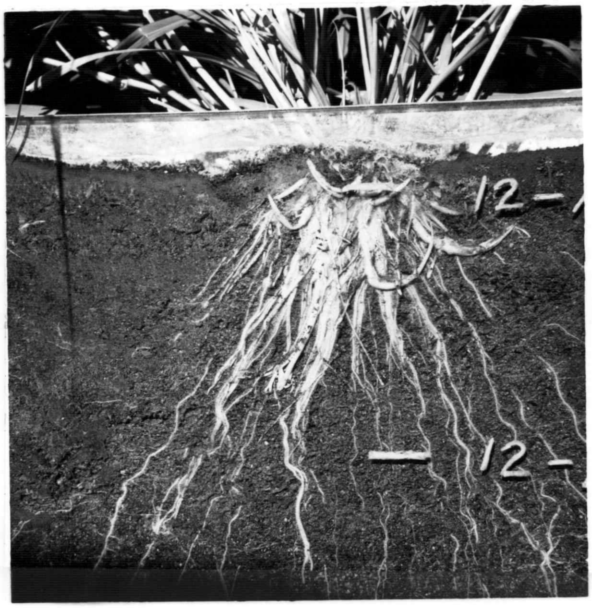

FIGURE 2. Rhizome development of a reed canarygrass plant 10 weeks after the seed was planted in a root box.

FIGURE 3. Reed canarygrass flowering 16 weeks after the seed was planted. Roots penetrated to the bottom of the root box in 10 weeks.

THE VERTICAL DISTRIBUTION OF REED CANARYGRASS TILLER AND RHIZOME BUDS

Introduction

The location of rhizomes in the soil profile is an important factor to consider in the development of control measures for a perennial plant. This is especially important if one is considering the use of soil-applied herbicides or soil fumigants on an area that cannot be tilled. Usually, herbicides that resist leaching are ineffective for the control of perennial plants because they do not leach far enough into the soil to reach the site of uptake. Of course, many edaphic and climatic factors play an important role in the leaching properties of a particular herbicide.

Evans and Ely (21), working on cropland in Ohio, reported that the maximum rhizome depth of reed canarygrass was 15.24 cm. The following study was conducted to determine if their data were applicable to reed canarygrass grown in continously saturated soils common to irrigation ditchbanks.

Methods and Materials

A trench 1.9 meters long and 6 to 9 dm deep was dug into the berm of the Roza irrigation canal to permit observation of the rhizomes of reed canarygrass plants grown under aquatic conditons (Figure 4). Most of the rhizomes were located in the upper 5 cm of soil, but it was difficult to ascertain the maximum depth of rhizome penetration. The roots and rhizomes were so dense that a rhizome could not be followed to the apex.

FIGURE 4. Roots and rhizomes of reed canarygrass exposed on the vertical plane of a trench dug into the berm of an irrigation canal. Soil was washed off the surface before the picture was taken. The bottom of the trench is the original sideslope of the canal.

Therefore, an indirect method to determine the maximum depth of effective rhizome penetration was undertaken. One square meter plots were arranged end-to-end along the bank of the Roza canal and excavated to depths of 0, 5, 10, 15, or 20 cm. After the excavations were completed, 2, 6-dichlorobenzonitrile (dichlobenil) granules were placed in an 8 to 10 cm band around the perimeter of each plot to prevent invasion of reed canarygrass from border areas. Previous experience had shown that dichlobenil did not injure plants outside the treated area. Two layers of dichlobenil were placed in the 10, 15, and 20 cm deep excavations; one at the bottom, and one 5 cm from the top of the excavation. One layer of dichlobenil was used at the bottom of the 5 cm excavation and around the non-excavated check plots. The plots were then filled to the original soil level with virgin topsoil. The experimental design was a randomized block with three replications.

Shoot counts were taken from each plot 1, 2, 3, and 4 months after excavating and backfilling. After shoot counts were recorded each month, the emerged shoots on plots that had been excavated were severed about 5 cm below the soil surface with an asparagus knife and removed from the plots. If they had not been severed at this depth, new buds would have formed on the crown and produced additional shoots. Thus, a reliable determination of the distribution and approximate number of viable buds could not have been obtained without their removal.

Results and Discussion

More than 1300 shoots per square meter were present on the non-excavated plots on each of the four observation dates (Table 2). This

TABLE 2. The vertical distribution of reed canarygrass rhizome and tiller buds as determined by the number of shoots that emerged from different soil depths during a four-month period.

Soil Depth (cm)	Emerged shoots per sq. meter			
	1 mo.	2 mo.	3 mo.	4 mo.
0-5	1811	1338	1352	1610
5-10	143	174	137	79
10-15	6	14	0	2
15-20	0.3	3	0	0.7
> 20	0	0	0	0

reveals that 88 to 95 percent of the non-dormant reproductive buds were located in the upper 5 cm of soil. Reasons why there were more shoots on the first date than at any other time are not clear. Possibly intra-specific competition resulted in the death of some weak shoots. It was very difficult to accurately count the number of shoots in the dense, rank sward by the second observation date, but it is doubtful if more than 10 percent error could be attributed to counting error alone.

The number of rhizome buds that produced shoots decreased rapidly below the 5 cm depth and again below the 10 cm depth. Thereafter, the decline in numbers of shoots was not as dramatic and there were still a few shoots that arose from a depth of between 15 and 20 cm. No shoots developed, and therefore it is assumed that no viable rhizomes were present, on plots that had been excavated to a depth of 20 cm.

These data agree closely with those of Evans and Ely (21). They indicate that unless a root absorbed herbicide is translocated in a basipetal direction, the herbicide would have to be leached to a depth of between 15 and 20 cm in order to be effective. Data presented in another section of this report show that a single bud located on a 4 cm lenght of rhizome was capable of producing a clone that occupied 6093 sq cm in a 13-month period. Therefore, approximately two rhizome buds per sq meter could completely revegetate an area within one growing season.

VARIATIONS IN REED CANARYGRASS COLLECTED FROM SIX DIFFERENT SITES

Introduction

Reed canarygrass along irrigation channels in the Pacific Northwest and Rocky Mountain States has responded erratically to field applications of amitrole-T and dalapon. Differences in susceptibility to these herbicides did not appear to be related to different environmental conditions. Preliminary work with plants cultured in the greenhouse also indicated that edaphic and/or climatic conditions were not responsible for the variation. Because there are several "strains" of reed canarygrass (1), this study was undertaken to determine if there were differences in the vegetative and reproductive characteristics of plants collected from six different canals in four states.

Methods and Materials

Reed canarygrass rhizomes were collected from the banks of irrigation canals near Huntley and Bozeman, Montana; Riverton, Wyoming; Caldwell, Idaho; and Sunnyside and Wapato, Washington. The rhizomes were potted in a mixture of sand, silt, and peat moss and propogated in the greenhouse for several months to increase the amount of rhizome material for field plantings.

On March 3, 1969, the plants were removed from the pots and rhizomes were dissected into 4 cm-long sections that contained one bud each. Individual rhizome sections were planted in 10-cm diameter pots and maintained in the greenhouse until May 1, 1969, when the plants were transplanted in the field. All topgrowth, except one shoot that contained two leaves, was clipped from each plant prior to placing it in the field. Height of the single shoot ranged from 5 to 7.5 cm.

Sixteen plants of a given selection were space planted (1.2 meter spacing) on each of four replicate plots. Plots were 4.9 meters square and they were arranged in a randomized block design. The field was rill irrigated at 1-week intervals throughout the study.

Measurements given in Tables 3 and 4, with the exception of basal area and the number of stems per plant, were taken on two random shoots on each of the four central plants of each plot between June 8 and 12, 1970. Therefore, data for each replication were based on eight subsamples.

Seed used for weight and germination determinations was harvested on June 19, 1970. Only mature seed that dehisced readily was used for the tests. Random lots of 100 seeds were removed from the bulk sample of each replication and subjected to germination tests under standard conditions (2) on June 22, 1970. Germination counts were recorded 7 and 16 days after placement of the seeds in the germinator. Seed used for weight determinations was dried at 23C for 7 days before the weight of 1000 seeds was determined.

Data were statistically analyzed and compared according to Duncan's Multiple Range Test.

Results and Discussion

In 1970 new shoots began to emerge from clones of all selections during the first week of March. Maximum and minimum temperatures at

TABLE 3. The maximum height that six reed canarygrass selections attained by the time of first flower emergence and during the 1970 season at Prosser, Washington. Descriptions of leaf color and posture were recorded at the time of first flower emergence.

Selection	Plant Height (cm) At flower emerg.	Plant Height (cm) Maximum	Leaf color and posture
Riverton	84 d[1/]	178 d	light green - lax
Sunnyside	91 c	171 e	blue green - erect
Bozeman	135 b	187 bc	medium green - lax
Caldwell	135 b	194 b	light green - lax
Huntley	159 a	217 a	dark green - erect
Yakima	137 b	186 c	light green - erect 2 % chlorotic

[1/] Means within columns followed by the same letter are not significantly different from each other at the 5% level of probability.

TABLE 4. The basal area, number of stems per plant, stem diameter and leaf dimensions of six reed canarygrass selections grown at Prosser, Washington in 1970. All data were obtained June 8 to 12, 1970.

Selection	Basal area per plant (sq. cm)	Stem		Leaf	
		No. per plant	Diameter (mm)	Length (cm)	Width (mm)
Riverton	3450 b[1]	360 a	5.7 b	37.1 a	21.9 b
Sunnyside	3189 b	342 a	5.0 c	30.0 c	20.7 bc
Bozeman	3884 b	356 a	5.6 b	36.8 ab	20.3 cd
Caldwell	6093 a	372 a	5.8 b	31.7 c	19.5 cd
Huntley	5074 a	306 a	8.4 a	35.0 b	24.4 a
Yakima	3079 b	170 b	5.6 b	31.2 c	19.1 d

[1] Means within columns followed by the same letter are not significantly different from each other at the 5% level of probability.

this time ranged from 4.4 to 9.4C and -4.4 to 1C, respectively. The selections from Riverton and Sunnyside began to flower on May 18, but the selections from Bozeman and Caldwell did not flower until May 27. Plants from Huntley and Yakima began to flower on May 24.

Although there was not a large difference in the flowering date of the six selections, there was a highly significant difference in plant height at the time of flowering (Table 3). The selection from Wyoming was only 84 cm tall when it began to flower, whereas the one from Huntley was 159 cm tall. At this stage of development plants from Bozeman, Caldwell, and Yakima ranged from 135 to 137 cm tall. The plants attained their maximum heights approximately 6 weeks after the first flowers emerged. The shortest selections at the time of flowering, those from Riverton and Sunnyside, made the most rapid growth during this 6-week period, but they still remained significantly shorter than the other selections. Height of these plants increased 111 and 88 percent following initial flower emergence, respectively, whereas the other four selections increased only 34 to 44 percent. Maximum shoot height ranged from 217 cm for the Huntley selection to 171 cm for the Sunnyside selection.

Differences in leaf color and posture of the leaves were also observed at the time of flowering. Leaf colors ranged from a blue green on the Sunnyside selection to a light green with 2 percent of the leaves chlorotic, on the selection from Yakima. Three of the selections had leaves that were lax or curved downward at the tip while the other three selections had erect leaves. Brief descriptions of these characteristics are given for each selection in Table 3.

The chlorosis noted for the selection from Yakima was observed numerous times while the plants were being propagated in the greenhouse. These observations indicate that this characteristic was not due to differences in culture or edaphic conditions, but rather to a basic genetic and physiological difference. Foliar sprays and soil drenches of ferrous chelate reduced the chlorosis in new growth of plant cultures in the greenhouse.

The basal area of clones established from 4 cm long rhizome sections in March 1969, ranged from 3079 to 6093 sq cm by June 1970. The selections from Caldwell and Huntley had significantly larger basal areas than the other selections which indicates that once established, these two selections would spread more readily than the others. The number of shoots per clone was not related to the basal area of the clone as was expected. With the exception of the Yakima selection, there were no differences in the number of shoots per clone. Apparently, there are large differences in the internode length as well as the total length of rhizomes produced by the selections.

Differences in rhizome morphology were observed at the time the clones were divided in the greenhouse. Rhizomes from the Caldwell and Huntley selections branched three to six and three to five times, respectively, before the central rhizome tip developed into a leafy shoot. The selections from Sunnyside, Yakima, and Riverton produced only non-branched rhizomes. Rhizomes of these selections terminated in a leafy shoot and there were many more buds at the base of emerged shoots than there were on those from Caldwell and Huntley. The latter type of rhizome development agrees with the description of reed canarygrass given by Evans and Ely (21). Rhizomes of the Bozeman selection were predominately non-branched, but two to three leafy shoots developed near their apex.

The length of the leaves on the six selections ranged from 30 to 37.1 cm and the leaf-width ranged from 19.1 to 24.4 mm. A maximum difference of 2.0 cm and 1.5 mm was needed for significance of these parameters at the 5 percent level of probability, respectively.

The diameter of the stems of plants from all locations except Huntley ranged from 5.0 to 5.8 mm. The latter selection had a stem diameter of 8.4 mm, which was almost 1.5 times larger than any other selection. The selection from Huntley was by far the most robust selection in the study. This selection ranked first or second in every parameter measured with the exception of seed weight and panicle length. Conversely, the selection from Yakima ranked fifth or sixth in every category except plant height.

The length of panicles, seed weight, and germination percentages of the six selections are given in Table 5. The panicles ranged from 18.3 cm long on the Yakima selection to 24.7 cm long on the one from Bozeman. There was an extremely large difference in the weight of the seeds produced by the plants. Seeds produced by the Caldwell selection were 37 percent lighter than those produced by the Sunnyside selection.

There were a number of highly significant differences in the germination percentages of the seeds 7 days after they were subjected to germination tests (Table 5). However, after 16 days in the germinator 97.5 to 99.7 percent of the seeds of all selections germinated. These are much higher germination percentages than reported by Vose (59) for

TABLE 5. A comparison of the panicle length, seed weight, and germination of six selections of reed canarygrass grown at Prosser, Washington in 1970.

Selection	Panicle length	Weight of 1000 seeds mg	Germination, %	
			7 Days	16 Days
Riverton	22.0 b[1]	1161.1 b	80.25 c	98.25 N.S.[2]
Sunnyside	20.6 bc	1236.2 a	87.00 abc	99.00
Bozeman	24.7 a	891.2 d	93.50 a	99.00
Caldwell	20.3 c	778.3 e	61.00 d	97.25
Huntley	20.2 c	1057.1 c	84.75 bc	99.75
Yakima	18.3 d	899.4 d	89.75 ab	97.50

1/ Means within columns followed by the same letter are not significantly different from each other at the 5% level of probability.

2/ N.S. means F test was not significant at the 5% level of probability.

freshly harvested seed. The author has consistently obtained 96 to 99 percent germination of reed canarygrass seed immediately after harvest.

These data show that there are a number of "strains" of reed canarygrass on the ditchbanks of the irrigation projects in the Pacific Northwest and the Rocky Mountain States. The rate at which this species replaces other vegetation on a ditchbank may be a function of the particular "strain" involved. Additional studies need to be conducted to ascertain the significance of these different "strains" from a weed control standpoint.

THE EFFECT OF DALAPON, AMITROLE-T, AND PARAQUAT ON THE TOTAL AVAILABLE CARBOHYDRATES IN REED CANARYGRASS RHIZOMES AND ROOTS

Introduction

The ability of a perennial plant to generate new growth each year is dependent to a large extent on the food reserves stored in the underground portions of the plant during the previous season. Therefore, the trend of carbohydrate reserves in the underground organs of reed canarygrass should be a reliable indication of the progressive effects of treatments used to control the grass. Also, many translocated herbicides such as dalapon and amitrole-T are known to move with the photosynthate stream. Determination of the carbohydrate trend in untreated plants at different growth stages may aid in determining the optimum time to apply translocated herbicides for maximum movement into the roots and rhizomes.

Methods and Materials

Herbicide Treatments

A site along the Roza Canal north of Sunnyside, Washington, was selected for the field plots. The site supported a dense stand of well-established reed canarygrass that had formed a berm 2.4 meters wide along the edge of the canal. Water from the canal inundated the reed canarygrass to a depth of approximately 10 cm most of the time during the summer months. Soil in the experimental area was composed entirely of silt collected from the irrigation water by the roots of the reed canarygrass plants.

Treatments included dalapon at 22 kg/ha, amitrole-T at 4.5 kg/ha, paraquat at 1.1 kg/ha, and an untreated control. All treatments were replicated three times on plots 13.7 meters long and 2.4 meters wide. The plots were arranged end-to-end along the canal bank in a randomized block design.

The initial herbicide treatments were applied on May 16, 1967. At that time reed canarygrass topgrowth ranged from 35 to 58 cm in height and the panicles were just beginning to emerge from the sheath. The amitrole-T and dalapon treatments were applied only once in 1967, but they were repeated twice on the same plots in 1968. Amitrole-T was reapplied on May 10, and July 9, 1968, and dalapon was reapplied on May 10, and August 9, 1968. Regrowth of the reed canarygrass plants was just beginning to flower at the time of each application. Paraquat was reapplied on June 5, July 7, August 7 and September 7, 1967 and on May 10, June 10, July 9, August 9 and September 5, 1968. Each herbicide was applied in 1120 l/ha of water that contained 3 ml/l of the surfactant X-77 (alkylarylpolyoxyethylene glycols).

Rhizome-root Sampling and Processing

Rhizome-root samples were taken from all plots the day before initial treatments were applied and at weekly intervals during the following month. Thereafter, samples were taken at approximately 1-month intervals until water was turned out of the canal in the fall (October 6, 1967). Samples were also collected from the untreated plots on four dates previous to May 16, and from November 1967 to May 1968 to provide complete information on the trend of carbohydrate reserves throughout the year. Rhizome-root samples were taken from all treatments on May 8, 1968, 2 days before the first retreatments were applied in 1968, and at approximately 1-month intervals until October 9, 1968.

A root sampler, similar to a soil-sample tube, was constructed from stainless steel thin-wall pipe that was 10.2 cm in diameter (Figure 5). After a rhizome-root sample was excavated, the foliage was severed from the underground organs about one cm below the soil level and the core of soil that remained was trimmed to a length of 30.5 cm. Four such subsamples taken from each plot on each sampling date were bulked and constituted a sample for analysis. Two of the subsamples were taken near the water's edge and two were taken about 1 meter away from the water's edge. Initial samples from each plot were taken 1.5 and 6.1 meters from the stake marking the upstream edge of the plot and each subsequent sample was taken 25 cm downstream from the previous sample. Samples taken at random would have resulted in undesirable trampling of the reed canarygrass topgrowth.

The soil was washed off the roots and rhizomes with a stream of water in the field within 30 minutes after the samples were collected. All dead or flaccid root and rhizome tissue was discarded, and the sample was surface dried with a stream of compressed air before fresh weights were recorded. The samples were dried at 100 to 105C for 1 hour to destroy enzymatic activity and then they were dried in a forced draft oven at 68 to 70C for 60 hours. Dry weights were recorded before the samples were ground to 40-mesh fineness, placed in glass bottles and dried at 70C to constant weight. The bottles were capped tightly, and stored for analysis.

FIGURE 5. Sampler used to extract the rhizome-root samples (left), and the sample after it had been trimmed to 30.5 cm in length and washed (right).

Total available carbohydrate analysis

Carbohydrates were extracted from duplicate 500 mg subsamples of each sample with 0.2 N sulfuric acid solution according to the method of Smith, Paulsen, and Raguese (56). After the samples were boiled gently for 1 hour they were cooled to room temperature and neutralized with a 15 percent solution of sodium hydroxide. The hydrolysate was filtered into 500 ml volumetric flasks and diluted to volume with distilled water.

Carbohydrate content of the extracts was determined by the anthrone method as modified by Kahan (36). One ml aliquots of the extract were reacted with 0.5 ml of the modified anthrone reagent and 6 ml of concentrated sulfuric acid prior to determining the optical density of the solutions. Optical densities were determined at a wavelength of 620 mu with a Beckman Model DBG spectrophotometer. If there was more than a two percent difference between the duplicate samples, additional subsamples were extracted and analyzed. Standard glucose solutions that contained 50, 100, 150 and 200 ug of glucose per ml were also prepared and the optical densities were determined each time samples were analyzed. The standard curve is shown in Appendix Figure 1. Results were expressed as percent total available carbohydrates on a dry weight basis (70C).

Results and Discussion

Seasonal Trends of Carbohydrates in Rhizomes and Roots of Untreated Plants as Related to Stage of Growth

The trend of total available carbohydrates, hereafter referred to as TAC, over a 19-month period is shown in Figure 6. The trend of TAC was generally downward after emergence of new growth in late February

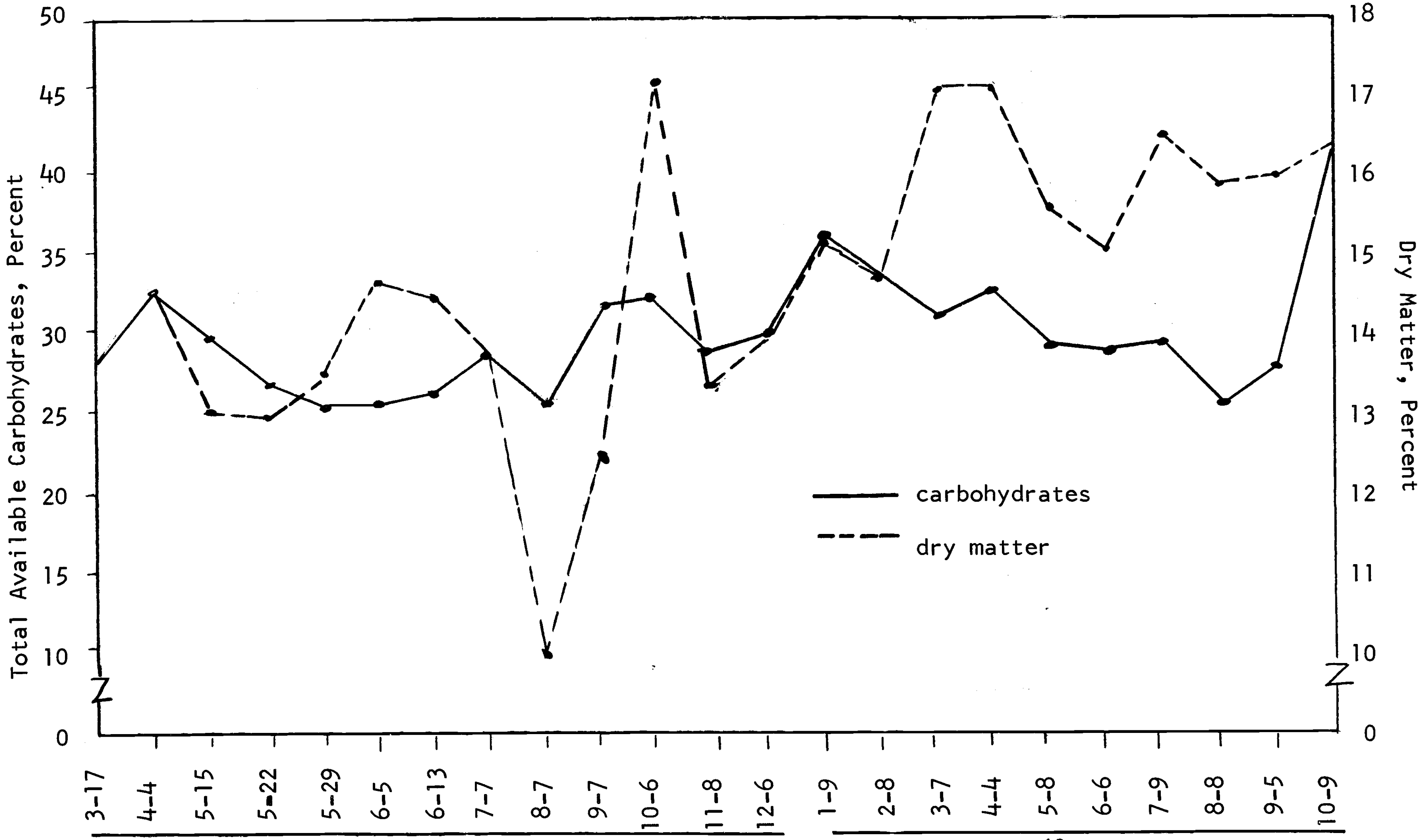

FIGURE 6. The trend of total available carbohydrates and percent dry matter in the rhizomes and roots of untreated reed canarygrass.

or early March. Carbohydrates reached one of two low ebbs for the season in late May or early June when the plants were in the late boot to early flower stage of development. The levels remained constant or increased slightly during June and July and then they decreased to the lowest level of the season in early August of each year. Aphids caused moderate to severe injury to the plants during the latter part of July of each year and numerous secondary shoots also developed from buds in the axils of the older leaves during this period. Possibly either or both of these were responsible for the slight, but consistent, decrease in carbohydrates between the July and August sampling dates.

Storage of carbohydrates in the rhizomes and roots was most rapid during the fall and winter months after reed canarygrass foliage began to turn yellow. This was especially evident in 1968 when the level increased from 25.8 percent on August 8 to 42.5 percent on October 9. These data indicate the herbicides applied in early August are likely to be most effective in preventing the build-up of carbohydrates in the underground portions of reed canarygrass.

Statistical analysis of the data showed a highly significant difference in the carbohydrate content and percent dry matter between sampling dates (Appendix Table 2). However, the coefficients of variation were 12.43 and 12.57 for TAC and percent dry matter, respectively. With these degrees of variability, mean differences of 6.20 for carbohydrates and 3.03 for percent dry matter were required between sampling dates for significance at the 5 percent level of probability.

Total avialable carbohydrates were significantly higher on October 9, 1968 than on any other sampling date except January, 1968 (Table 6).

TABLE 6. Relation of developmental stage of reed canarygrass to total available carbohydrates and dry matter content in the rhizomes and roots.[1]

Date of Sampling	Total carbohydrates (percent)		Total dry matter (percent)		Plant height (cm)
March 17, 1967	28.77	c-e	13.7	a-d	5
April 4	32.67	b-e	14.7	a-d	30
May 15	30.20	b-e	13.1	b-d	53[2]
May 22	27.08	c-e	13.0	c-d	71
May 29	25.91	e	13.5	b-d	82
June 5	26.20	e	14.7	a-d	93[3]
June 13	26.79	d-e	14.5	a-d	116
July 7	29.16	c-e	13.7	a-d	110[4]
August 7	25.83	e	9.2	e	118
September 7	32.04	b-e	12.5	d	120
October 6	32.54	b-e	17.2	a	123[5]
November 8	29.21	c-e	13.4	b-d	-
December 6	30.33	b-e	14.1	a-d	-
January 9, 1968	36.41	a-b	15.2	a-d	-
February 8	33.87	b-c	14.8	a-d	-
March 7	31.25	b-e	17.1	a	17
April 4	33.33	b-c	17.1	a	32
May 8	29.87	c-e	15.6	a-d	53[2]
June 6	29.33	c-e	15.1	a-d	136[3]
July 9	29.50	c-e	16.5	a-b	140[4]

TABLE 6. (Continued)

Date of Sampling	Total carbohydrates (percent)	Total dry matter (percent)	Plant height (cm)
August 8	25.75 e	15.9 a-d	142
September 5	28.30 c-e	16.0 a-c	142
October 9	42.46 a	16.4 a-c	142[5/]

[1/]Means in a column followed by the same letter are not significantly different from each other at the 5% level of probability; a-d means a, b, c, and d, etc.

[2/]Panicles just beginning to emerge from the sheath.

[3/]Plants in full flower.

[4/]Seed mostly shattered.

[5/]Leaves beginning to turn yellow.

However, TAC present in January, 1968, were no different from those present in December, 1967, or in February, March, and April, 1968, or April and May, 1967. The level of carbohydrates was significantly below the January, 1968, level for the first time each season in mid-May when the panicles were just beginning to emerge from the sheath. With these few exceptions, the trends of percent TAC (Figure 6) did not represent statistically significant changes between sampling dates. Several additional replications of the field plots would have been required for mean differences of 1 or 2 percent between TAC levels on different sampling dates to have been significant.

The percent total dry matter varied more between dates of sampling than the percent of TAC in 1967, but it varied less than the TAC in 1968. Dry matter content ranged between 13.0 and 14.7 percent from March until July 1967, and then it receded to 9.2 percent by August 7. It increased significantly between August and September and again between September and October 1967. Thereafter, the percent dry matter remained relatively constant throughout the remainder of the study. There were no statistical differences in the percent dry matter between sampling dates in 1968.

Effects of Treatments on Reed Canarygrass Topgrowth

The tips of the leaf blades turned brown or chlorotic within 1 week after treatment with dalapon or amitrole-T on May 16, 1967. By July, these symptoms spread to the leaf and stem tissue of the upper half (approximate) of plants treated with amitrole-T or throughout those plants treated with dalapon. Dalapon destroyed the axillary buds on the stems, but amitrole-T did not affect such buds. Plants treated with amitrole-T developed new shoots from the auxillary buds as well as from crown and rhizome buds between July and August 1967, and by September these plants had flowered. Regrowth in October of 1967 ranged from 61 to 102 cm tall on plots treated with amitrole-T and it was completely normal in color. Regrowth from rhizome and crown buds began to develop about 1 month later on plants treated with dalapon than on those treated with amitrole-T. However, by October there were no significant differences between the height of regrowth on plots treated with amitrole-T and dalapon.

Paraquat at 1.1 kg/ha caused rapid browning of the leaves, but it did not affect the stem tissue appreciably. Within 1 week after treatment, many plants produced one or two new leaves near the stem apex and inflorescences continued to emerge. Although paraquat was applied to the same plots at approximately 1-month intervals throughout the summer, new inflorescences emerged between each of the treatment dates. Dense, normal colored regrowth that ranged from 13 to 90 cm tall developed between each treatment interval in 1967.

Retreatments were applied for the first time in 1968 on May 10. With the exception that the maximum height of plants in the dalapon and paraquat-treated plots was 33 and 42 percent less than untreated plants on this date, respectively, there were no visible symptoms attributable to the treatments applied in 1967. The maximum height of plants treated with amitrole-T and of untreated plants was 91 cm. After treatments were applied, injury symptoms developed at the same rate and to the same degree in 1968 as in 1967; eg., dalapon caused complete browning, amitrole-T affected only the upper half of the foliage, and new inflorescences were produced between each application of paraquat. Regrowth 40 to 91 cm tall developed on the plots treated with amitrole-T by July 9, 1968. Ninety percent of the foliage on dalapon-treated plants was necrotic in early July, but by August 8 dense regrowth ranged from 38 to 79 cm in height and the plants were beginning to flower. The second applications of amitrole-T and dalapon made on July 9, and August 8, 1968, respectively, did not prevent the plants from flowering before the last observations were made on October 9, 1968. On the latter date, there was only 8, 5, and 27 percent stand reduction on plots treated with dalapon, amitrole-T and paraquat, respectively.

Effect of Amitrole-T and Dalapon on Carbohydrate Reserves

The effects of amitrole-T and dalapon on the TAC levels in the rhizomes and roots of reed canarygrass were very similar throughout the study. There was a statistically significant difference (.05 level of probability) between these two treatments on only one of 15 sampling dates (Table 7). On September 7, 1967, TAC contributed 16.7 and 24.4 percent of the total solids in the plants treated with dalapon and amitrole-T, respectively. A difference of 4.67 percent was required for significance on that date.

The level of TAC in plants treated with these two herbicides was not significantly lower than the level in untreated plants until 2 months after treatment, July 7, 1967. Carbohydrate levels continued to decline during the following month and they reached their lowest level of the 1967 season on August 7 (Figure 7). On this date, TAC in plants treated with amitrole-T and dalpon constituted only 18.4 and 15.8 percent of the total dry weight of the rhizomes and roots as compared

TABLE 7. Effects of three herbicides on the total available carbohydrates in the rhizomes and roots of reed canarygrass on 15 sampling dates.

Date of Sampling	Percent total available carbohydrates[1]			
	Untreated check	Amitrole-T	Dalapon	Paraquat
May 15, 1967	30.20 b a	29.33 ab a	27.58 a-d a	30.87 a a
May 22	27.08 b a	24.25 b-e a	27.62 a-c a	24.91 b-c a
May 29	25.91 b a	23.62 b-f a	28.58 ab a	24.66 b-d a
June 5	26.20 b b	31.08 a a	30.37 a a	23.50 b-c b
June 13	26.79 b a	24.79 b-d a	26.04 b-e a	20.71 c-e a
July 7	29.16 b a	22.08 d-f bc	23.29 e b	18.29 c-f c
August 7	25.83 b a	18.37 fg b	15.79 f b	16.33 ef b
September 7	32.04 b a	24.37 b-d b	16.71 f c	17.67 d-f c
October 6	32.54 b a	23.42 b-f b	24.66 c-e b	16.33 ef c
May 8, 1968	29.87 b a	28.04 a-c a	29.04 ab a	26.92 ab a
June 6	29.33 b a	25.25 a-d ab	23.91 d-e ab	20.04 c-e b
July 9	29.50 b a	22.58 c-f b	23.29 e b	20.04 c-e b
August 8	25.75 b a	18.67 e-g ab	17.00 f b	22.58 b-d a
September 5	28.30 b a	14.41 g b	18.75 f b	14.75 f b

TABLE 7. (Continued)

Date of Sampling	Percent total available carbohydrates [1/]			
	Untreated check	Amitrole-T	Dalapon	Paraquat
October 9	42.46 a a	29.00 ab b	23.91 d-e bc	20.33 c-e c

[1/] Each value is an average of three replicate samples. Letters in horizontal lines indicate the rank of means for treatments within each date of sampling. Letters in vertical columns indicate the rank of means for dates within each treatment. Means in the same line or column followed by the same letter are not significantly different from each other at the 5% level of probability; b-e means b, c, d, and e, etc.

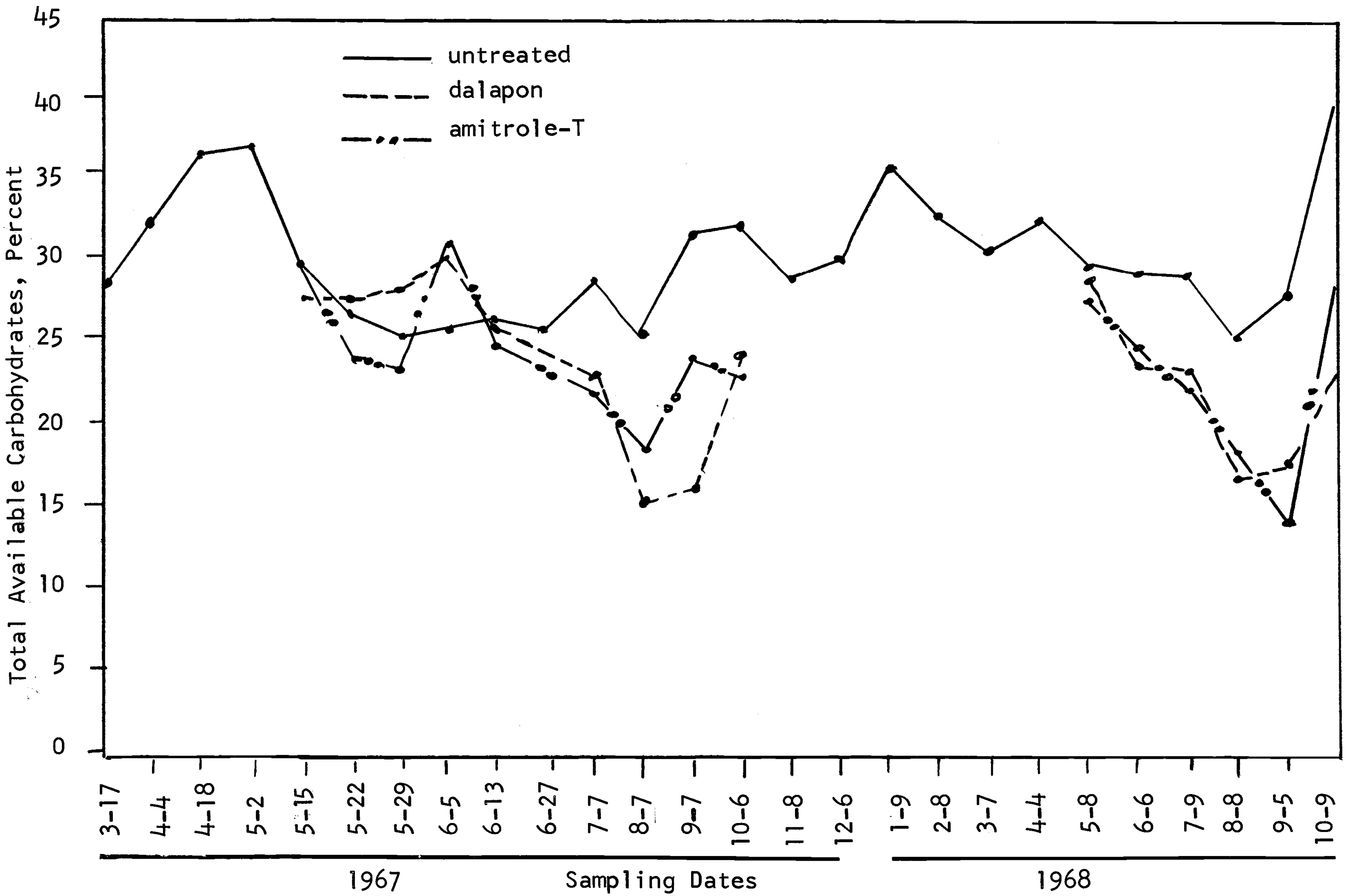

FIGURE 7. Effects of amitrole-T and dalapon on the total available carbohydrates in the rhizomes and roots of reed canarygrass.

with 25.8 percent for untreated plants. Thereafter, the levels of carbohydrates in the treated plants began to increase slightly. However, they remained significantly lower than the level in untreated plants for the remainder of the 1967 season. When the last samples were taken in 1967 (October 6), the carbohydrate level in plants treated with amitrole-T and dalapon were 28 and 24 percent less than those in untreated plants, respectively.

Samples collected 2 days before the first treatments were applied in 1968, May 8, contained the same quantity of carbohydrates as the untreated plants. As in 1967, the level of carbohydrates in treated plants was not significantly different from untreated plants until 2 months after the treatments were applied, July 9, 1968. They remained below the level in untreated plants for the remainder of 1968 season. However, by the last sampling date, October 9, 1968, the TAC level in plants treated with amitrole-T was not significantly different from the level present on May 8, (Table 7).

On October 9, 1968, the level of TAC in plants treated with dalapon was beginning to recover from the second application of the herbicide on August 8. Although TAC in plants treated with amitrole-T and dalapon were not significantly different from one another on this date, the level found in the dalapon-treated plants was significantly lower than on May 8, 1968.

Only one application of either herbicide was made in 1967 and two applications were made in 1968. However, there was no significant difference between the TAC levels in the rhizome and roots on October 6, 1967 and October 9, 1968. These data indicate that neither dalapon nor amitrole-T seriously affected the ability of reed canarygrass to generate new growth from rhizome and tiller buds and the new growth rapidly replenished the food reserves in the underground portions of the plant.

The affect of amitrole-T and dalapon on the carbohydrates in the rhizomes and roots of reed canarygrass were similar to those reported for quackgrass by LeBaron and Fertig (38) and for johnsongrass by McWhorter (45). However, the carbohydrate levels were restored to normal more rapidly in reed canarygrass than in quackgrass.

Effect of Paraquat on Carbohydrate Reserves

The level of TAC in plants treated with paraquat declined significantly within 1 week after treatment and it continued to decline gradually until July 7, 1967 (Figure 8). However, when compared with untreated plants on each of the sampling dates, TAC levels in treated plants did not differ significantly from the latter until July 7, 1967, (Table 7).

Repeated applications of paraquat in July, August, and September 1967 did not result in further significant reductions of carbohydrates. On October 6, 1967, the TAC level in untreated plants was reduced to 50 percent of the level in untreated plants. However, by the time the first samples were collected in the spring of 1968, May 8, the TAC level in treated plants had increased to 90 percent of the level present in untreated plants.

With the exception of the August sampling date, the TAC in paraquat-treated plants did not differ significantly within sampling dates between years. On August 8, 1968, the rhizomes and roots contained

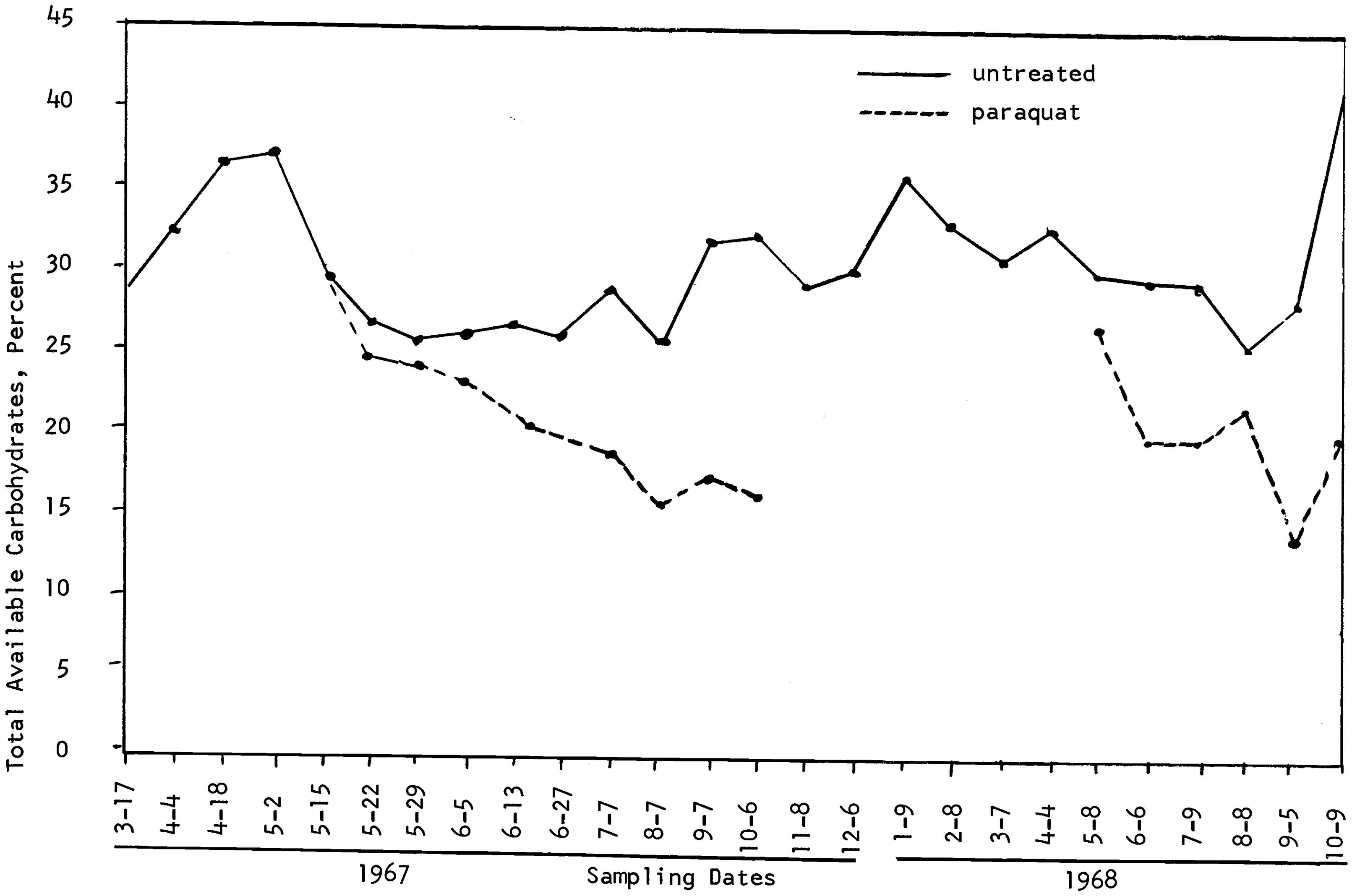

FIGURE 8. The effect of paraquat on the total available carbohydrates in the rhizomes and roots of reed canarygrass.

22.6 percent TAC whereas, on August 7, 1967, they contained only 16.3 percent TAC. The extreme necrosis caused by the large aphid population in late July and early August of 1967 may have contributed to this difference.

These data indicate that reed canarygrass would be extremely difficult to control with methods of weed control that depend upon starvation of the rhizome-root system for success. To be effective, treatments would have to be applied more frequently and later in the fall and/or earlier in the spring than they were in this study.

EFFECT OF HERBICIDES UPON ESTABLISHED REED CANARYGRASS AND PLANT SUCCESSION

Introduction

Previous to the introduction of organic herbicides that were effective on monocotyledonous species, frequent mowing and/or burning and draglining were used to temporarily control reed canarygrass on irrigation ditchbanks. More recently increased labor costs and air pollution laws have restricted or prohibited the use of these weed control methods. Irrigation project managers report costs as high as $1,133 per kilometer of channel for the removal of reed canarygrass and the associated berm that it forms. They also estimate the cost of mowing at $80 to $90 per kilometer per year at current wage rates. Obviously, these methods of control are feasible only in isolated and unique situations.

As previously mentioned, most of the herbicides currently in use for the control of reed canarygrass are only partially effective or they result in a ditchbank void of vegetation. Amitrole-T is the only herbicide that has controlled reed canarygrass effectively without destroying all of the associated grasses (31). However, the United States Government prohibits the use of this herbicide on irrigation projects that it owns and operates. The Bureau of Reclamation and Bureau of Indian Affairs operate a vast system of irrigation systems in the Western United States and they are seriously affected by this ruling.

Three field experiments were conducted between 1966 and 1969 to evaluate several herbicides for the control of reed canarygrass. Only herbicides that were known to be effective for the control of monocotyledonous plants were evaluated. All experiments were conducted on heavily infested ditchbanks near Sunnyside and Wapato, Washington. The infestation near Sunnyside was located on a berm consisting of soil particles that had eroded from an area characterized by Warden fine sandy loam. Soils adjacent to the Wapato canal are classified as Naches sandy loam.

Experiment No. 1

Methods and Materials

This experiment was conducted during 1966 and 1967 near Sunnyside to compare amitrole-T, dalapon, and TCA with several herbicides or herbicide combinations that had not been evaluated previously for the control of reed canarygrass. Post-emergence treatments compared with these three herbicides were as follows: (1) dalapon plus TCA at 22 plus 13 kg/ha, and 11 plus 6.5 kg/ha, respectively, (2) monosodium methanearsonate (MSMA) at 9 kg/ha, (3) disodium methanearsonate at 9 kg/ha, (4) 2,3,5-trichloro-4-pyridinol (pyriclor) at 5.6 kg/ha, (5) paraquat at 1.1 kg/ha, and (6) amitrole-T plus paraquat at 4.5 plus 1.1 kg/ha. The latter combination was applied to separate plots in two different manners; both herbicides were applied as separate sprays on the same day or the paraquat was applied 7 days after the amitrole-T application.

Post-emergence treatments were applied for the first time on May 12, 1966. Reed canarygrass ranged from 35 to 142 cm tall at that time. The taller plants were located in a band 30 to 45 cm wide adjacent to the water line and these plants were just beginning to flower. There was an estimated 1 to 2 percent stand of redtop, a desirable ditchbank grass, in the understory at the time of treatment. Treatments that caused perceptible injury to reed canarygrass were repeated on the same plots when the regrowth was just beginning to flower. On July 5, 1966, plots that had been treated with amitrole-T, amitrole-T + paraquat, paraquat, or pyriclor were retreated at the original rates of application. None of the other plots were retreated in 1966. The dead foliage was burned off the experimental area in February 1967, and all plots were retreated again on May 12, 1967. Also (2,4-dichlorophenoxy) acetic acid (2,4-D) at 2.2 kg/ha was added to the dalapon or dalapon plus TCA solutions to control annual broadleaved weeds and seedling Canada thistle (Cirsium arvense (L.) Scop.). Reed canarygrass ranged from 33 to 63 cm tall on May 12, 1967. Treatments that contained amitrole-T or pyriclor were reapplied on July 6, 1967 and those that contained dalapon were reapplied on August 22, 1967.

Herbicides evaluated as pre-emergence treatments were bromacil, prometone, TCA, and dalapon. Rates of application are given in Table 8. Reed canarygrass was burned off the plots with a propane burner 2 weeks before these herbicides were applied on November 16, 1966. Water was turned out of the canal on October 25, 1966 and the soil was still extremely moist at the time of treatment. Precipitation totalled 6.6 cm between November 16, 1966 and March 25, 1967, when water was turned back into the canal.

One-half of each plot treated with TCA or dalapon in November, 1966 was seeded with redtop at a rate of 11 kg/ha on April 14, 1967. The seed was broadcast by hand and raked into the surface soil.

TABLE 8. Percent control of reed canarygrass with herbicides applied as pre-emergence and post-emergence sprays in 1966 and 1967 at Sunnyside, Washington.

Treatment		Estimated Control on date indicated					
		1966			1967		
Chemical	Rate kg/ha	7/5	9/6	10/19	5/9	7/6	10/2
Dalapon + TCA	22 13	98	95	76	28	91	57
Dalapon + TCA	11 6.5	89	72	57	16	62	24
Dalapon	22	96	91	70	33	87	52
Amitrole-T + Paraquat	4.5 1.1	30	7	2	0	12	0
Amitrole-T + Paraquat[1/]	4.5 1.1	66	20	17	21	47	16
Amitrole-T	4.5	56	30	5	15	23	18
Pyriclor	5.6	71	81	75	63	72	50
Bromacil	17	-	-	-	0	50	30
Bromacil	8.5	-	-	-	10	17	16
Prometone	17	-	-	-	5	17	13
Prometone	8.5	-	-	-	0	3	0

TABLE 8. (Continued)

Treatment		Estimated Control on date indicated					
		1966			1967		
Chemical	Rate kg/ha	7/5	9/6	10/19	5/9	7/6	10/2
TCA	22	-	-	-	95	45	24
TCA	44	-	-	-	99	80	62
TCA	88	-	-	-	99	90	72
Dalapon	22	-	-	-	98	23	21
Dalapon	44	-	-	-	98	46	22
Dalapon	88	-	-	-	99	57	27
Untreated	-	0	0	0	0	0	0

[1]Paraquat was applied 7 days after the amitrole-T application.

Plots were arranged end-to-end along the canal bank in a randomized block design. Each treatment was replicated three times on plots 6 meters long and 2.4 meters wide. Herbicides were applied in 1122 l/ha of water with a knapsack sprayer operated at a pressure of 2.11 kg/sq cm. The surfactant X-77 was added to all post-emergence spray solutions at a rate of 3 ml/l.

Visual estimates of percent control were made by two individuals, and the averages of these estimates are given in Table 8. Control values were based on stand and height of the plants as compared with the untreated check plants.

Results and Discussion

The most effective post-emergence treatments evaluated were dalapon at 22 kg/ha and the combination of dalapon at 22 kg/ha plus TCA at 13 kg/ha. One application of either treatment in 1966 provided 91 to 98 percent control of reed canarygrass for 4 months. Regrowth began to develop in early September and by October 19, control had diminished to 70 and 76 percent, respectively, Table 8. Even though the plants were in a weakened condition at the onset of winter, they recovered rapidly during the spring of 1967 and on May 9, 1967, 3 days before the retreatments were applied, control was only 33 and 28 percent, respectively. The retreatment applied on May 12, 1967, controlled the reed canarygrass adequately until the first part of August when regrowth began to develop profusely. A second retreatment, applied on August 22, 1967, was not as effective as the previous one and by October 2, there was only 52 and 57 percent control on plots treated with dalapon and dalapon plus TCA, respectively.

Uneven emergence of shoots from rhizome buds and the protection of the newly emerged shoots from the spray solution by the dead plant tissue are believed to have contributed to the poorer control obtained with the August 22 retreatment. All of the old growth was burned off the plots in February 1967, and thus the dead plant material was not present on May 12.

The combination of dalapon at 11 kg/ha plus TCA at 6.5 kg/ha initially was almost as effective as the combination at the 2X rate. However, at the termination of the experiment, control was in proportion to the rate of application.

A host of annual broadleaved weeds and seedling Canada thistle developed in 1967 on areas where the stand of reed canarygrass was reduced by treatments that contained dalapon. Redtop was not killed by such treatments, but the plants' vigor was reduced sufficiently to prevent it from spreading.

None of the treatments that contained amitrole-T or paraquat provided adequate control of reed canarygrass. The combination of amitrole-T and paraquat applied on the same date was completely ineffective. As expected, the paraquat destroyed the vascular system before amitrole-T could be absorbed and translocated out of the foliage. When paraquat was applied 7 days after the amitrole-T application, control was only slightly better than the control obtained with amitrole-T alone. Putnam and Ries (51) found that quackgrass plants treated in such a manner displayed severe chronic amitrole symptoms. Regrowth of reed canarygrass following these treatments was completely normal.

The organic arsenicals, DSMA and MSMA, were completely ineffective for the control of reed canarygrass. Paraquat at 1.1 kg/ha desicated the leaves on the upper one-third to one-half of the stem, but new growth from axillary buds was evident within 1 to 2 weeks after treatment. Control by this treatment was very temporary and none was evident on the observation dates given in Table 8. Negative data for these three treatments were not included in the table.

Two applications of pyriclor per season provided adequate control of reed canarygrass, but it also destroyed the redtop. In 1967 the bank began to crack and topple into the canal on one of the treated plots. Therefore, this herbicide was not considered to have potential for use on ditchbanks.

Pre-emergence applications of TCA at 44 and 88 kg/ha were the most effective treatments evaluated. Both treatments reduced the stand of reed canarygrass 30 to 45 percent and they maintained 62 and 72 percent control, respectively, for the entire season, Table 8. The 22 kg/ha rate of TCA and dalapon at 22, 44, and 88 kg/ha provided 95 to 99 percent control of reed canarygrass early in the season, but the level of control diminished rapidly after about July 1. Usually, vegetation immediately adjacent to the water's edge is much more difficult to control with herbicides than the vegetation located at a distance of about 45 cm or more from the water's edge. However, fall applications of TCA and dalapon controlled reed canarygrass equally well on both areas. Figure 9 illustrates the control obtained with these two herbicides on May 30, 1967. There were no differences between dalapon and TCA or between rates of application on this date.

FIGURE 9. Control of established reed canarygrass with fall applications of TCA (left) or dalapon (right) at 22 kg/ha. The treatments were applied on November 16, 1966 and the photographs were taken on May 30, 1967.

In April 1967, seedlings of several annual and perennial broad-leaved weeds, as well as redtop, began to emerge on plots treated in the fall of 1966 with dalapon or TCA. Excellent stands of redtop developed on both the seeded and non-seeded portions of all plots except those that were treated with TCA at 88 kg/ha. Only an estimated 25 to 30 percent stand of redtop developed on the non-seeded portion of the latter plots. Apparently, at the higher application rate sufficient TCA residue was present in the soil to destroy the seedlings that emerged early in the season.

The banks of the canal were seeded with redtop at the time it was constructed. Although reed canarygrass had essentially replaced the redtop in a 3 to 4 meter band along the water's edge, there was an excellent stand of redtop higher on the bank. Seed produced by these plants was probably deposited on the treated areas and masked the effect of seeding the treated areas.

Although bromacil at 8.5 kg/ha was as effective as prometone at 17 kg/ha, neither treatment controlled reed canarygrass satisfactorily. Bromacil at 17 kg/ha controlled 100 percent of the reed canarygrass on the area above the waterlevel in the canal, but control at and below the waterlevel was insignificant (Figure 10). No other species invaded the area where reed canarygrass was controlled with bromacil. However, rhizomes from the band of reed canarygrass along the water's edge began to penetrate this area by October, 1967.

Results of this experiment showed that TCA and dalapon were the most effective herbicides for the control of reed canarygrass. Observations of plant succession on plots treated with dalapon indicated that

FIGURE 10. Control of established reed canarygrass on the dry portion of a ditchbank with bromacil at 17 kg/ha and the lack of control below the waterlevel. The treatment was applied on November 16, 1966 and the photographs was taken on July 6, 1967.

proper timing of the application may play an important role in the selectivity of this herbicide.

Experiment No. 2

Methods and Materials

This experiment was also conducted along the Roza Canal near Sunnyside to determine the optimum time of applying dalapon at 22 kg/ha for the control of established reed canarygrass. Initial herbicide treatments were applied at the following stages of plant development: (1) rapid vegetative growth (45 to 50 cm tall), (2) early flower, (3) seed mature (approximately 80 percent of the seed dehisced) (4) mature (leaves beginning to turn yellow) and, (5) dormant (November).

The experiment was begun in 1967 and retreatments were applied in 1967, 1968, and 1969 at the time that regrowth reached the designated growth stage. A total of four applications were made at growth stages 1, 2, and 3, but only two applications were made at growth stages 4 and 5 before the experiment was terminated in the fall of 1969. By August 9, 1968, reed canarygrass plants that survived the initial treatment and a host of seedlings that had attained a height of about 45 cm dominated the plots where reed canarygrass was treated at the dormant stage in November, 1967. Dalapon at 22 kg/ha was applied on August 9, 1968 to control these plants. Thus, a total of three treatments, two at the dormant stage and one to control the plants that developed during the intervening summer, were made on these plots. Also, the entire experimental area was treated with 2,4-D at 3 kg/ha in May of 1968 and 1969 to control annual broadleaved weeds.

The experimental design was a randomized block with three replications. Individual plots 6 meters long and 2.4 meters wide (the width of the infestation) were arranged end-to-end along the canal bank. Treatments were applied in the same manner as described for Experiment No. 1 and the surfactant X-77 was added to all spray solutions at a rate of 3 ml/1.

Visual estimates of percent control and stand, as compared with the untreated check, were made by two individuals in late May and early September of 1968 and 1969. Also, all vegetation was clipped at ground-level from four random 929 sq. cm. quadrats in each plot and sorted by species on August 6, 1969. The samples were dried at 100 C for 72 hours before dry weights were recorded.

Results and Discussion

Established reed canarygrass was most susceptible to dalapon when initially treated at a dormant stage. Two repeated applications in November of 1967 and 1968 reduced the stand of reed canarygrass 97 percent and permitted a dense stand of redtop to develop from natural seeding of the treated areas (Figure 11). The treatment applied in August 1968 to prevent the surviving plants and newly developed seedlings from maturing probably contributed significantly to the effectiveness of this treatment. However, it did not affect the stand of reed canarygrass which increased from 43 percent of control levels to 85 percent during the 1968 season (Table 9).

Dry weights of reed canarygrass and redtop harvested from the plots are shown graphically in Figure 12. Although reed canarygrass contributed

FIGURE 11. A dense stand of redtop that developed on plots where dormant reed canarygrass was treated with dalapon at 22 kg/ha in 1967 and 1968. The picture was taken on August 4, 1969.

TABLE 9. The estimated percent control and stand of reed canarygrass treated at five growth stages with dalapon at 22 kg/ha. The experiment was conducted near Sunnyside, Washington.

Growth Stage	Stand on date indicated:				Control on date indicated:			
	5-22-68	9-16-68	5-28-69	9-8-69	5-22-68	9-16-68	5-28-69	9-8-69
Rapid growth	75	58	52	62	92	87	97	97
Early flower	95	98	88	83	20	92	18	95
Seed mature	100	100	87	97	0	33	0	62
Plant mature	92	100	55	97	90	0	92	0
Dormant	43	85	3	3	95	99	99	99
Untreated	100	100	100	100	0	0	0	0

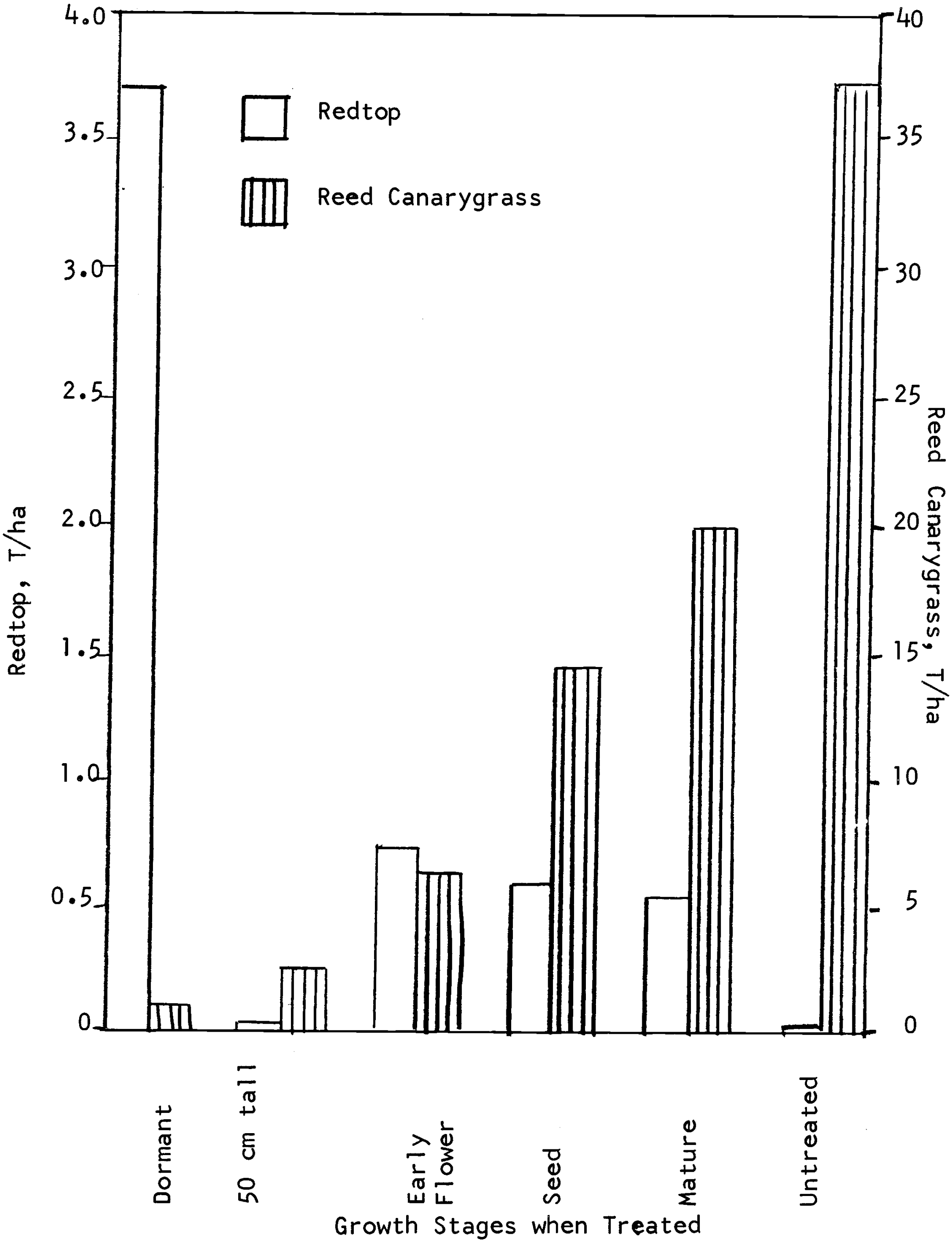

FIGURE 12. The yield of reed canarygrass and redtop following applications of dalapon at 22 kg/ha to reed canarygrass at five growth stages. Plants were harvested on August 6, 1969.

21 percent of the total dry weight harvested from the plots treated when the reed canarygrass was in a dormant stage, the yield was only 3 percent of that harvested from the untreated plots. Conversely, the yield of redtop increased from .03 T/ha on the untreated plots to 3.7 T/ha on the treated plots. The conversion of a reed canarygrass sod to a redtop sod on ditchbanks is extremely beneficial to the irrigation project manager. Redtop does not interfere with the flow of water and it binds the soil sufficiently to prevent erosion. The species is also an effective competitor against annual broadleaf and grass weeds. Unfortunately, the experimental area was destroyed by a dragline and additional observations on the rate of reinfestation by reed canarygrass were not possible.

Four repeated treatments of dalapon at the time reed canarygrass plants were making rapid vegetative growth (45-50 cm tall) also provided excellent control of the grass, but the stand was reduced only 39 percent (Table 9). Moreover, applications at this growth stage did not permit the stand of redtop to increase and invade the areas where the stand of reed canarygrass was reduced. Thus, it appears that if the treatments were continued over a period of time sufficient to eliminate the reed canary grass, the ditchbank would become subject to erosion.

Treatments applied at the early flower, mature seed, and mature stages of growth were successively less effective than those applied at an earlier growth stage or when the plants were dormant (Figure 12). The foliage of plants treated at the early flower growth-stage was severely damaged by the treatments, and only sparse regrowth developed during the remainder of the season in which the treatment was applied. However, by May of the following year there was abundant regrowth and control was estimated to be only 18 to 20 percent at that time (Table 9). Moreover, the stand of reed canarygrass was reduced only 17 percent by four repeated applications at the early flower growth-stage. Thus, dalapon applied to reed canarygrass plants that are just beginning to flower acts as a very effective "growth inhibitor" without affecting the stand appreciably. In certain locations, such a treatment may be better than one that kills the entire plant. If the underground portion of reed canarygrass plants located on coarse soils and extremely steep banks was destroyed, these areas would be highly susceptible to erosion, and inhibition of the topgrowth would be the preferable means of managing vegetation on such areas.

These results show that dalapon can be used effectively to manipulate the relative abundance of redtop and reed canarygrass in mixed populations. It appears that either species may be maintained as the dominant species, dependent upon the season or growth stage that the herbicide is applied.

Experiment No. 3

Methods and Materials

The experiment was initiated in 1967 to compare several rates of TCA for the control of reed canarygrass on Naches sandy loam. This soil is characterized by a gravel layer beneath a relatively thin layer of sandy loam topsoil. Also, the effect of applying amitrole-T at 4.5 kg/ha during the second year of the study was compared with no follow-up treatment to control seedlings and established plants that escaped the TCA treatments.

Rates of TCA evaluated were 44, 88, 134, and 176 kg/ha. The two lowest rates were evaluated as single late fall (November 11, 1967) applications and as split-applications; one-half of the total herbicide was applied in the fall and the remaining one-half was applied in the spring (March 6, 1968). The 134 and 176 kg/ha rates were applied as single treatments in the fall. A light rain was falling at the time of treatment on November 11, and a total of 7.2 cm of precipitation was received before water entered the canal on March 30, 1968.

The senescent reed canarygrass was not burned off the plots prior to application of the fall treatments because it was partially green and the cost of burning it would have been prohibitive on a commercial scale. By February 1968, the grass was dry and it was burned off the plots prior to the application of the spring treatments. On May 29, 1968, all plots were treated with 2,4-D at 2.2 kg/ha to control a host of annual broadleaved weeds that invaded the treated areas.

Treatments were replicated four times on plots 6 meters long and 3.6 meters wide. The plots were arranged end-to-end along both banks of a drainage canal near Wapato, Washington, in a randomized block design. Two replications were located on either side of the canal. The canal drained the surrounding farmland and it flowed only during the irrigation season; March to October.

Two replications of each TCA treatment were treated with amitrole-T at 4.5 kg/ha on May 9, 1969 and two replications were not treated. Reed canarygrass seedlings were 2 to 15 cm tall at that time. All replications were seeded with redtop at 4.5 kg per acre on June 4, 1969. The seed was broadcast on the plots by hand, but it was not worked into the surface soil because the area along the waterline was extremely rocky.

The TCA treatments were applied in 1122 l/ha of water and amitrole-T was applied in 561 l/ha. The surfactant X-77 was added to the amitrole-T solution at a rate of 3 ml/l. Treatments were applied in the same manner as previously described.

Results and Discussion

With the exception of the split-application at 22 plus 22 kg/ha, all rates of TCA controlled 88 to 98 percent of the reed canarygrass until the middle of July, 1968 (Table 10). Thereafter, control diminished rapidly on plots treated with the split application at both rates and on those treated in the fall with the 44 kg/ha rate. On September 29, 1968, control by the latter treatments ranged from 10 to 57 percent. At rates of 88 kg/ha and higher, 88 to 97 percent control was maintained for the entire irrigation season.

The split-applications were significantly less effective than single fall applications at equivalent dosages. Only 1 mm of precipitation was received between the spring application and March 30, when water began to flow in the canal. Thus, the herbicide applied on March 6, was not leached into the soil prior to the time that the canal water flowed over the treated area along the waterline and removed the herbicide. Moreover, only 1.5 and 3 mm of precipitation were received in April and May, respectively. Soil temperatures 2.5 cm below the surface rose to 17C during April and May and undoubtedly they were somewhat higher at the soil surface. Loustalot and Ferrer (40) found that the biological

TABLE 10. The effect of treatment rate on the control of reed canarygrass with single and split-applications of TCA. The experiment was conducted on Wapato Drain No. 1 in 1967 and 1968.

Application Rate kg/ha	Estimated Control in 1968 on date indicated		
	5-29	7-12	9-20
44	79	88	20
88	98	98	88
134	98	98	96
176	99	98	97
22 + 22 1/	55	65	10
44 + 44 1/	94	90	57

1/ Applied as split applications on November 11, 1967 and March 6, 1968.

activity of TCA on corn was reduced by 87 percent after storage of the treated soil for 2 months at 20 to 30C. Probably most of the herbicide applied on March 6 was decomposed before it was leached into the root zone.

In May of 1968, numerous species invaded the bare areas where the stand of reed canarygrass was reduced or eliminated by the TCA treatments. The most prominent invader species were common mullein (*Verbascum thapsus* L.), prickly lettuce (*Lactuca scariola* L.), white sweetclover (*Melilotus alba* Desr.), curly dock (*Rumex crispus* L.), tansy mustard (*Descurainia pinnata* (Walt) Britt.), common lambsquarter (*Chenopodium album* L.), western goldenrod (*Solidago occidentalis* Nutt.), western waterhemlock (*Cicuta douglasii* (DC.) Coult. and Rose), yellow foxtail (*Setaria glauca* (L) Beauv.), barnyard grass (*Echinochloa crusgalli* (L). Beauv.), and Canada thistle. A single application of 2,4-D at 2.2 kg/ha on May 29, 1968 controlled most of the broadleaved species sufficiently to permit observation of the remaining reed canarygrass plants for the remainder of the season.

Reed canarygrass seedlings began to emerge on the treated plots in March 1969, especially in an area 20 to 40 cm wide along the waterline. Also numerous seedlings of the species previously listed invaded the experimental area again in 1969. The reed canarygrass seedlings and the established plants that survived the TCA treatments developed normally and they dominated the plots by mid-summer. By September 9, 1969, control had diminished to 25 percent or less on all plots within the two replications that were not treated with amitrol-T at 4.5 kg/ha on May 9, 1969. Conversely, 37 to 95 percent control was maintained for the entire season on those plots that were treated with amitrole-T.

A comparison of the estimated control of reed canarygrass in September of 1968 and 1969, and the effect of the single amitrole-T treatment on the control maintained in 1969 is shown in Figure 13. The follow-up treatment of amitrole-T resulted in significantly higher control levels in 1969 than were evident in 1968 on plots that were originally treated with 44 kg/ha of TCA in the fall or with either of the split-applications. At treatment rates of 88 kg/ha or higher, control diminished 2 to 28 percent in 1969 in spite of the follow-up treatment with amitrole-T.

These data indicate that reed canarygrass cannot be eliminated from a ditchbank with TCA at rates up to 176 kg/ha. Although the 88 kg/ha rate was less effective than the 134 and 176 kg/ha rates, it provided adequate control for an entire season at considerably less cost than the two higher rates.

Redtop seed germinated readily on the areas that were treated with amitrole-T 4 weeks prior to sowing the seed on the soil surface. Establishment was most successful in the area immediately adjacent to the waterline. Surface soil moisture in the area 40 or more cm distant from the waterline was very poor and few seeds germinated and survived in that area. The redtop seedlings along the waterline grew normally and no symptoms characteristic of amitrole injury were observed. Redtop seedlings did not become established on the plots that were not treated with amitrole-T. The seeds germinated, but they succumbed to the extreme competition from the reed canarygrass seedlings. This was not surprising as reed canarygrass has been observed to invade and completely choke out an established stand of redtop on irrigation ditchbanks.

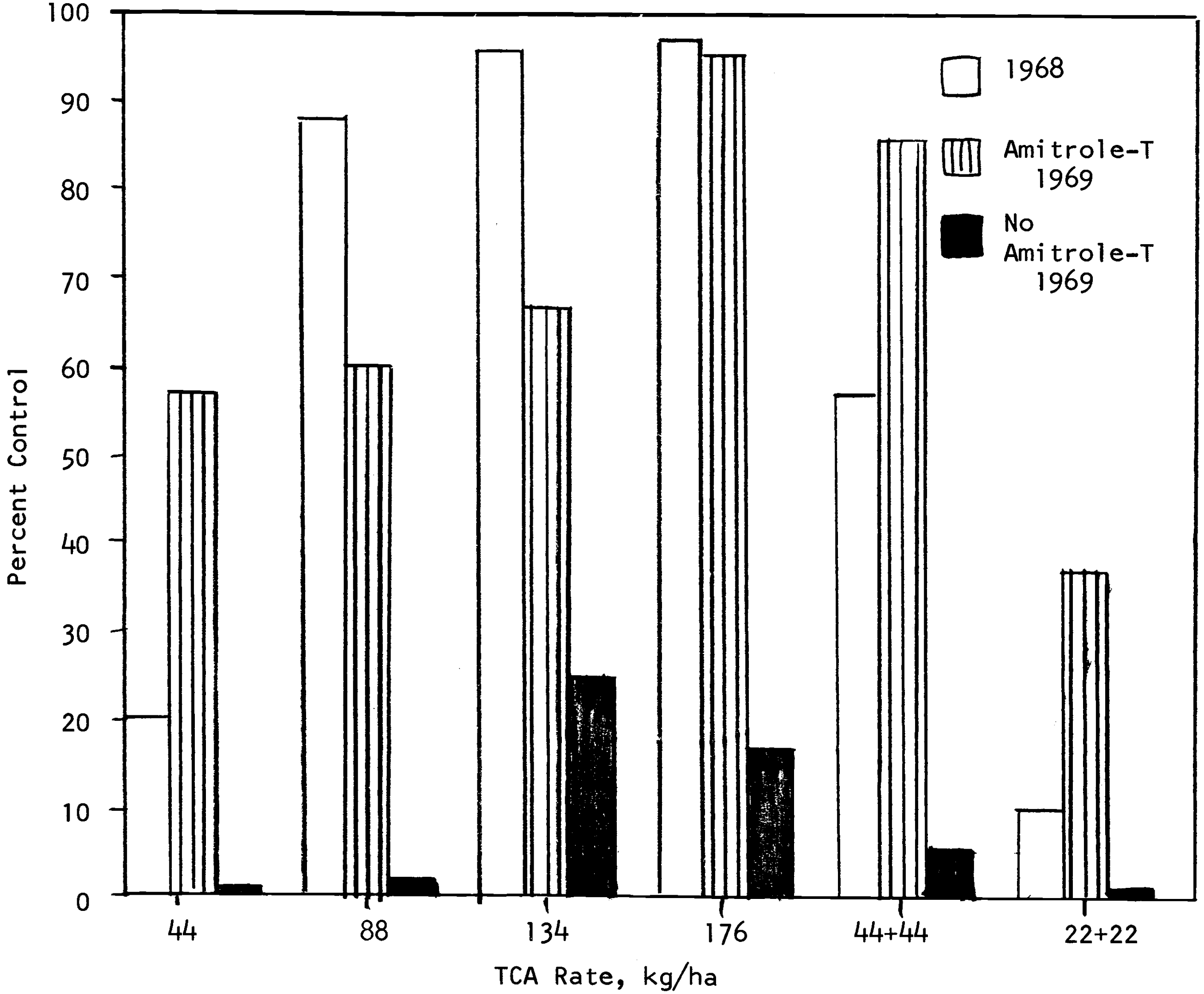

FIGURE 13. The effect of amitrole-T applied at 4.5 kg/ha in May, 1969, on the reinvasion of a ditch-bank by reed canarygrass following applications of TCA in the fall of 1967 for control of the established stand.

Most irrigation projects do not have sufficient resources to treat all of their infested ditchbanks in a single season. Moreover, treatment of the total infested area in one season may result in a build-up of harmful and illegal herbicide residues in the irrigation water. Therefore, treatment of only a portion of the total infested area in any given year may be all that is possible or desirable. The rate of reinfestation by seedling reed canarygrass probably would be considerably less than was observed in this experiment if treatments were applied to infestations located at the upstream-end of canals before the downstream sections were treated. There was an extremely dense infestation of reed canarygrass for several kilometers upstream from the experimental site where this study was conducted and seed from these areas undoubtedly contributed to the rapid rate of seedling establishment on the treated areas.

TCA IN IRRIGATION WATER FOLLOWING FALL APPLICATIONS OF THE HERBICIDE FOR WEED CONTROL ON CANAL BANKS

Introduction

TCA, applied in the fall after irrigation water was turned out of the canals, was the most effective and economical herbicide evaluated for the control of reed canarygrass on ditchbanks. Because reed canarygrass grows at and below the waterline, complete coverage of the infested areas requires treatment of a 30 to 60 cm-wide band below the normal waterline as well as the infested area above the waterline. Such application could result in the contamination of irrigation water the following spring. If the irrigation water contained herbicide residues, crops could be damaged and/or illegal residues of the herbicide may be taken up by the crop plants. No work has been reported concerning the amount of TCA in irrigation water following fall applications for the control of ditchbanks weeds. Information of this nature is needed before any herbicide can be fully evaluated for use on or around water. This was the basis for conducting this residue study.

Methods and Materials

General

Three laterals located on the Wapato Irrigation Project near Wapato, Washington, were selected for the study. Both banks of all three laterals were treated in November 1969, with TCA at a rate of 82 kg/ha. The herbicide was applied in 1400 l/ha of water with a multi-nozzle boom suspended from a truck. The reed canarygrass was partially lodged and the overlap of the spray below the normal waterline ranged between 30 and 60 cm. A constant overlap could not be maintained because of irregularities in the canal banks in relation to the roadway traversed by the sprayer.

The first water to traverse the laterals in 1970 was sampled for TCA residues. Sampling stations were located at the upper end (headgate) of each lateral, 0.8 and 1.6 kilometers downstream from the headgate, and then at intervals of 0.8 to 3.2 kilometers thereafter (Appendix Tables 5, 6, and 7). The distances between sample sites below the 1.6-kilometer stations were not uniform between laterals because of the excessive number of residue samples that would have been required on the longer laterals.

Water samples from the canal that supplied water to the laterals under study were collected immediately before, and 4 and 8 hours after the first flow of water into the laterals. These samples were used to determine background levels of TCA. Water from the Yakima River, which supplies the main canal, was used to determine recovery values. One-pint water samples were collected in triplicate at each of the sampling stations when the front of water reached a station and 1/4, 1/2, 3/4, 1, 2, and 4 hours later. In addition, triplicate samples were also collected at the most downstream station on each lateral 8, 24, and 48 hours after the first sample at that station was collected. Water samples were collected in polyethylene bottles and frozen until analysed for TCA residues.

Campbell Lateral

This lateral, 4 kilometers long, was the shortest lateral used in the study. A volume of 0.7 cubic meters per second of water was turned into the lateral on April 1 and this flow was maintained throughout the sampling period. There were check dams at all sampling stations except those at the extreme upper and lower ends of the lateral. Water was backed up to the normal waterline throughout the lateral.

East Lateral

On March 25, 1970, 1.7 cubic meters per second of water were turned into the east lateral and 3 hours later the volume was reduced to .85 cubic meters per second in order to prevent the lateral from overflowing at the lower end. This lateral was not checked up to the extent of the Campbell Lateral and the water level ranged from 15 cm to 30 cm below the normal waterline in the upper 5.6 kilometers of channel. Downstream from the 6.4-kilometer station, the water level was slightly above the normal water line.

The east lateral divided into two smaller laterals at a check-dam located 6.4 kilometers below the headgate. One of these smaller laterals was treated with TCA in the same manner as the East Lateral and the other lateral was not treated. The untreated lateral provided an opportunity to determine the fate of TCA in water as it passed over untreated soil. All of the other laterals discharged into drains where the dilution factor was enormous and such information could not be obtained. Two sampling stations were established on the untreated lateral 1 and 2 kilometers (the end of the lateral) below the 6.4-kilometer station.

Also, a single sampling station was established at the end of the treated lateral, 2 kilometers below the 6.4-kilometer station.

Lateral 4

Lateral 4, 14.5 kilometers in length, was the longest lateral studied. On March 20, 1.7 cubic meters per second of water were turned into the lateral and this volume was maintained throughout the sampling period. The water level was about 40 cm below the normal waterline for a distance of 3.2 kilometers below the headgate. Check dams 3.2, 4.8, 6.7, 8.5, 9.1, 10.4, 11.2, 12.3, 13.0, and 13.8 kilometers below the headgate forced the water up to within approximately 20 cm of the normal waterline in the areas just below the check dams and up to the normal waterline immediately upstream from the check dams. In the lower 2.5 kilometers of the lateral, the water was 5 to 10 cm above the normal waterline.

Sample Analysis

Analysis of all samples was by gas-liquid chromatography. Extraction and analysis of TCA were made following the methods reported by Frank and Demint (23) with the exception that the column, detector, and injector port temperatures were 145, 195, and 240C, respectively. Also the carrier gas flow-rate was increased to 50 ml per minute. The retention time was slightly more than 2 minutes and the average recovery of 4 to 400 ppb of TCA in 500 ml of water was 88.5 percent. The data for all samples were corrected accordingly, using an Rf of 1.13.

Results and Discussion

Campbell and East Laterals

As expected, the maximum and average concentration of TCA in irrigation water increased at each succeeding downstream station within the laterals (Figures 14 and 15). Average concentrations of TCA are calculated averages over a 4-hour period and they are weighted according to the length of time that a given concentration was detected at each of the sampling stations. The average concentrations of TCA at the 4-kilometer station on the Campbell Lateral (last sampling station) and the 4.8-kilometer station on the East Lateral were 36 and 32 ppb, respectively. Therefore, the average TCA concentration increased 7 to 9 ppb for each kilometer of treated canal that the water traversed.

Maximum concentrations of TCA detected in the East and Campbell Laterals did not increase uniformly between stations that were equidistant apart, either between or within laterals. This was expected because of the variable spray overlap, differences in soil moisture and temperature between the time the herbicide was applied and the date of sampling, and the number and height of check dams in the laterals. TCA is degraded rapidly in moist soil at temperatures above 10C. Soil temperatures on ditchbanks often vary by 10C or more because of differences in exposure and the amount of vegetative cover. Therefore, the extent of degradation of TCA would be extremely variable. Also, the maximum concentration would be related to the volume of water in a lateral. Despite these differences between and within the East and Campbell Laterals, the maximum concentrations of TCA at the ends of the laterals were identical when based on the number of miles of canal that the water had traversed.

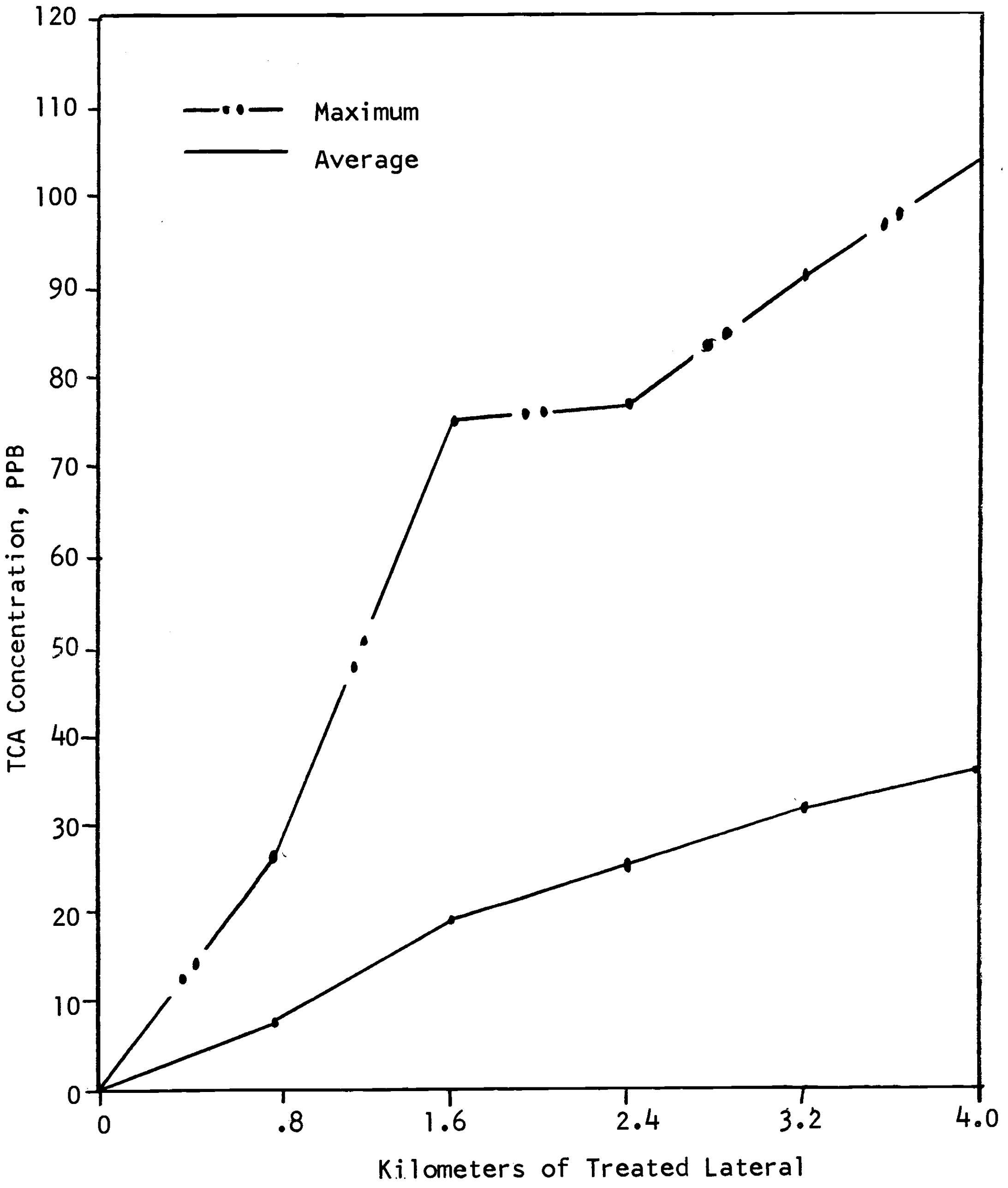

FIGURE 14. Maximum and average concentrations of TCA in irrigation water at each sampling site on the Campbell Lateral during the first 4 hours of water flow.

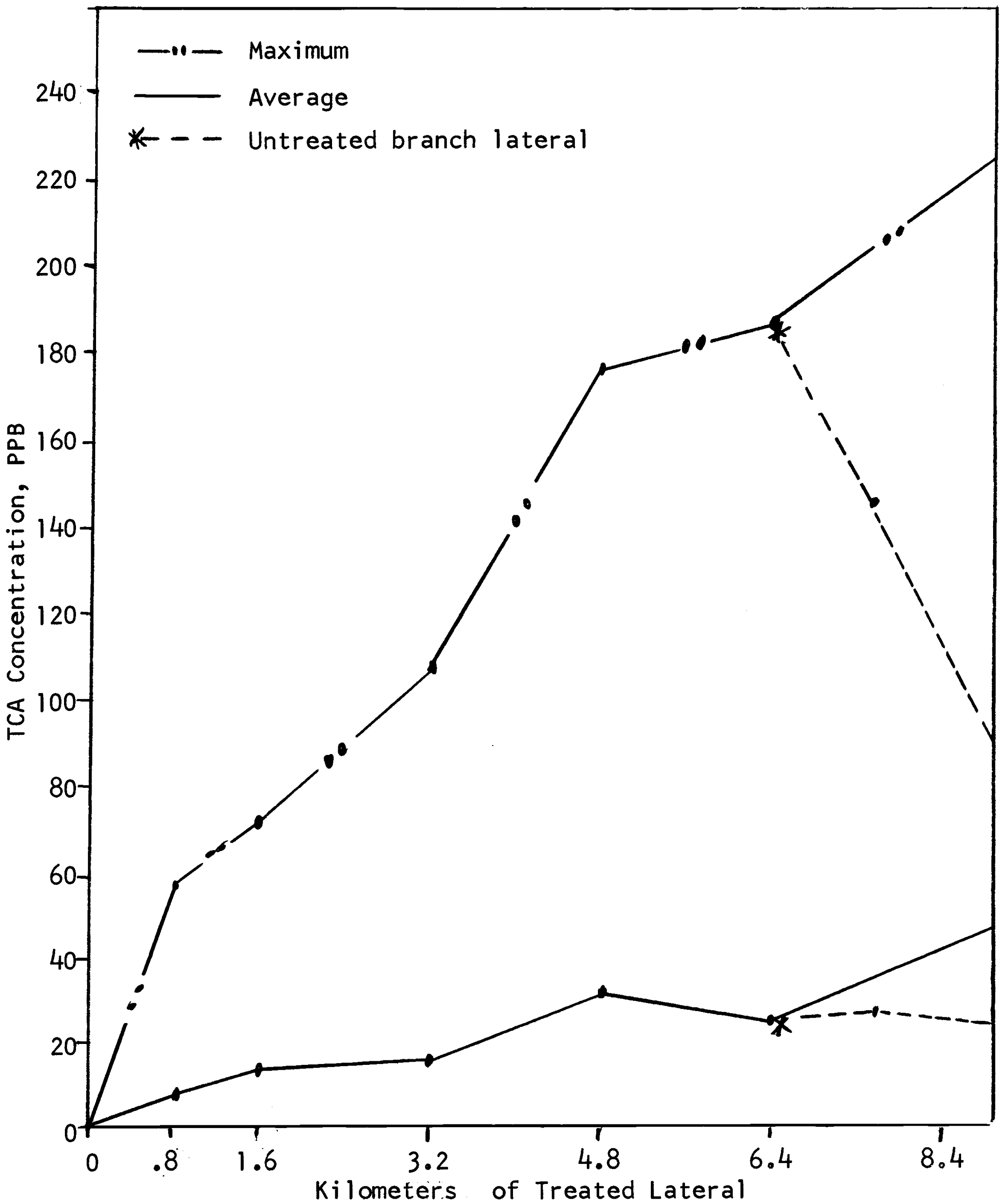

FIGURE 15. Maximum and average concentrations of TCA in irrigation water at each sampling site on the East Lateral during the first 4 hours of water flow.

The maximum concentration at the end of the two laterals was 225 and 104 ppb, respectively. Thus, the maximum concentration of TCA in the water increased 26.6 ppb for each kilometer of treated canal. Residues in these two laterals, and especially the Campbell Lateral, should have been the maximum obtainable from the laterals, because the water level was at or near the normal waterline.

From the limited data provided by this study, it does not appear that any loss of TCA occurred when the herbicide bearing water passed over untreated soil. In the untreated branch lateral that commenced at the 6.4-kilometer station of the East Lateral, the average concentration at the beginning and end of the lateral (2 kilometers long) was 25.5 and 25.2 ppb, respectively. However, the maximum concentration was reduced from 187 to 91 ppb over the 2-kilometer section. The latter reduction was undoubtedly due to dilution.

The length of time that water flows over soil that has been treated with a herbicide before no further residue is picked up from the soil is just as important as the maximum and average concentrations of herbicide in the water. Figures 16 and 17 show the quantity of TCA in irrigation water at each of the sampling intervals. Four hours after the first water flowed through the Campbell and East Laterals, the residue level had decreased to 3.3 and 5.4 ppb, respectively. Only a trace (<1 ppb) was detectable after 8 hours and no TCA could be found in the water after 24 and 48 hours (Appendix Tables 5 and 6).

The highest concentrations of TCA were found 1/4 and 1 hour after the first flow of water past a sampling station in the East and Campbell Laterals, respectively. Residue levels fell rapidly, once the peak

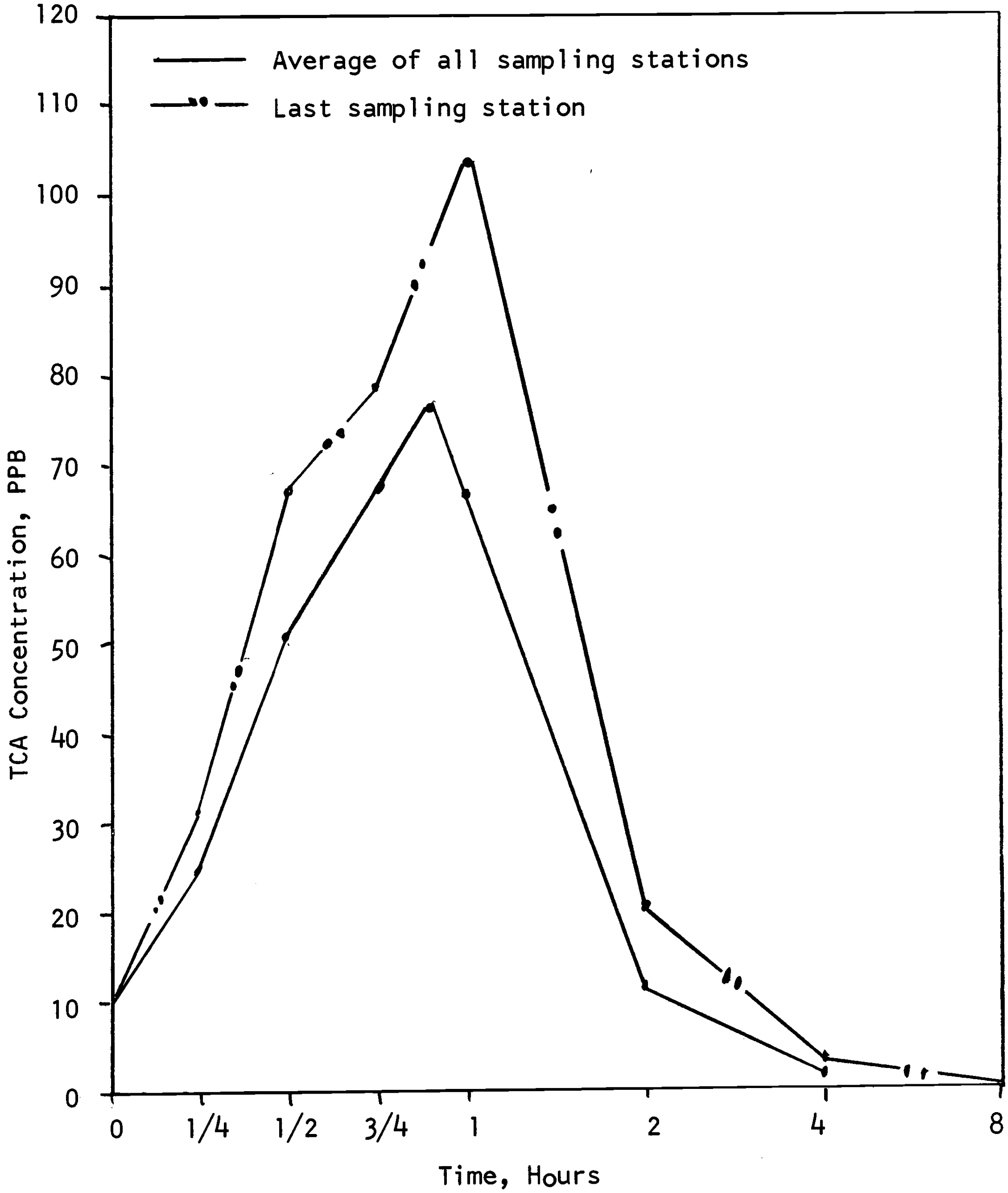

FIGURE 16. The concentration of TCA in irrigation water during the first 8 hours that water flowed through the Campbell Lateral.

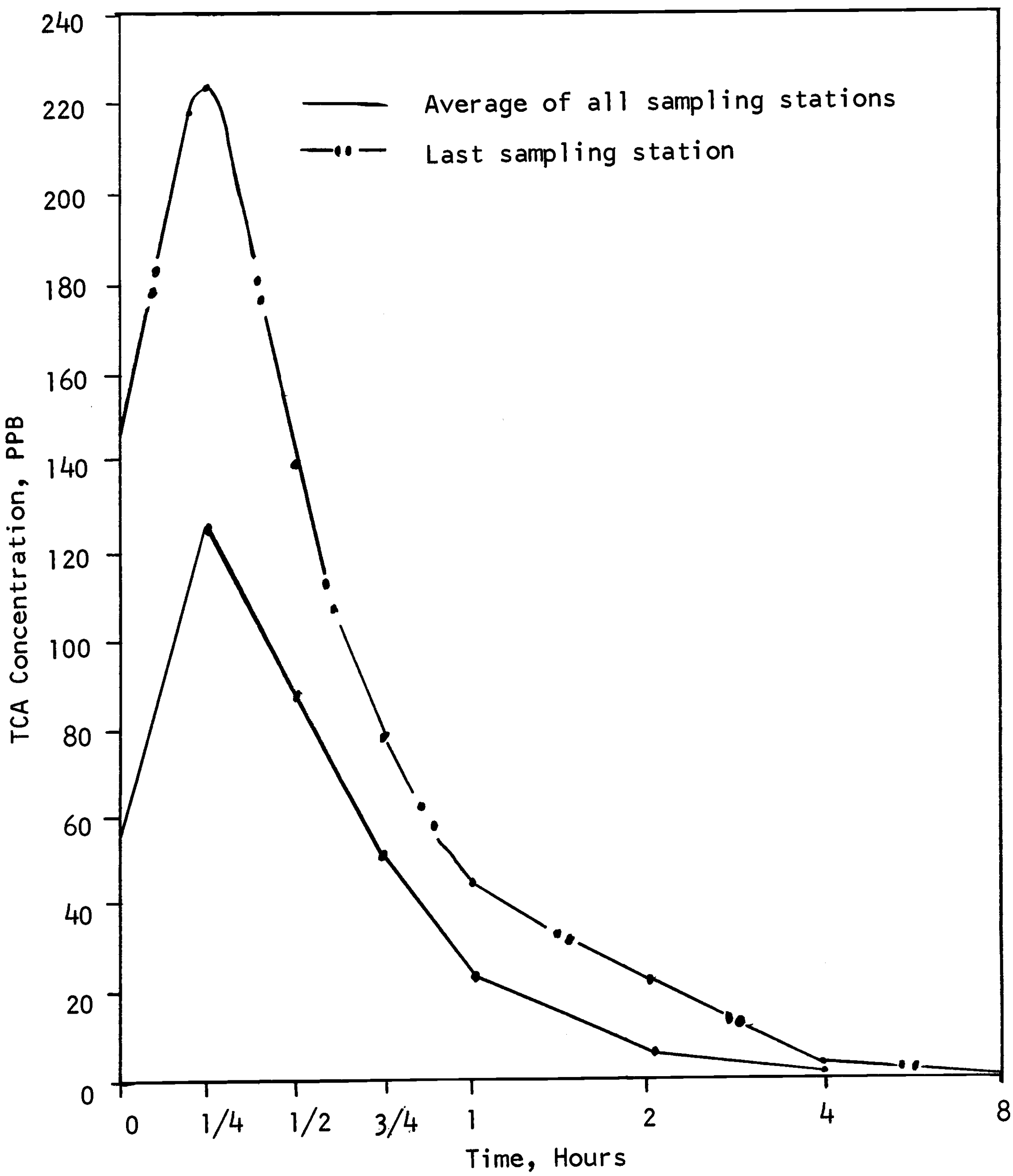

FIGURE 17. The concentration of TCA in irrigation water during the first 8 hours that water flowed through the East Lateral.

concentration passed a station. The number and height of check dams undoubtedly influenced the time when the maximum concentration was detected. Water was checked-up considerably more in the Campbell Lateral than in the East Lateral, and this delayed the time that the maximum concentration was detected at the downstream sampling sites.

Lateral No. 4

Residue levels found in Lateral No. 4 were considerably different from those in the East and Campbell Laterals. The average and maximum concentrations of TCA increased as the water flowed downstream, but they increased at a much lower rate than in the other laterals. The average concentration of TCA in the water at the most downstream sampling station (14.5-kilometer station) during the first 4 hours that water flowed through the canal was only 34 ppb (Figure 18). The average concentration at the 11.3, 8.0, 4.8, and 1.6-kilometer stations was 17, 8, 5, and 2 ppb, respectively. Thus, the average concentration of TCA was approximately doubled for each 3.2 kilometers that the water flowed downstream. If the water level in the canal had been uniform and extended up to the normal waterline, the relative increase in concentration at each successive downstream sample site would not have been this great. However, the absolute values would have been much larger.

The maximum residue level found at each sample site followed a trend similar to the average levels. There was an abrupt and dramatic increase in the quantity of herbicide that entered the water between the 11.3 and 14.5-kilometer stations. At the 11.3-kilometer station there were a maximum of 47 ppb of TCA in the water, but after traversing only 3.2 additional kilometers of lateral, the water contained a maximum

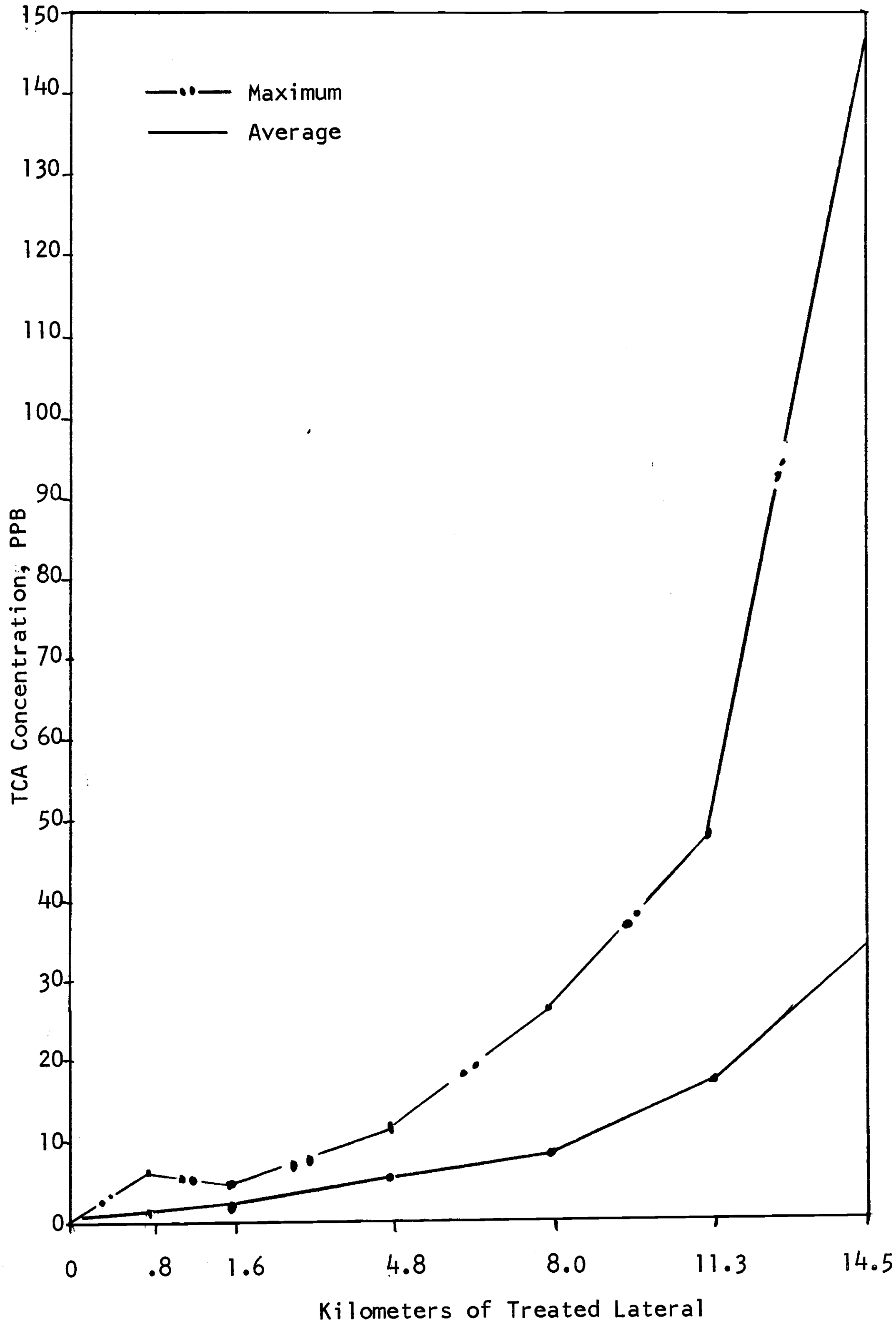

FIGURE 18. Maximum and average concentrations of TCA in irrigation water at each sampling site on Lateral 4 during the first 4 hours of water flow.

of 145 ppb. The volume of flow in relation to the cross sectional area of the lateral was probably responsible for the rapid increase in concentration in the lower 3.2 kilometers of channel. The lateral normally carries 5.7 cubic meters per second in the upper section and about .8 cubic meters per second in the lower section when water is being delivered to farmers. The difference between these two values is used by farmers along the lateral. However, no water was delivered to farms when the laterals were being filled. Therefore, the water level was well below the normal waterline in the upper section of the lateral and 5 to 10 cm above the normal waterline in the lower section. Data for Lateral 4 are probably characteristic of medium-sized laterals that decrease in carrying capacity rather rapidly from the upper to the lower end of the lateral.

Because the residue level at the most downstream sampling station on Lateral 4 was so large in comparison to the other stations, the average TCA concentrations shown in Figure 19 are somewhat misleading. With the exception of the 4.8 and 14.5-kilometer stations, the maximum concentration of TCA was present in the water 1/4 to 3/4 hour after the first water passed a station (Appendix Table 7). At the 4.8-kilometer station, there were equal (approximate) quantities of TCA in the water at the 0, 1/4, and 1/2-hour sampling intervals and then the residue level began to decline rapidly.

The first water that passed the 14.5-kilometer station contained 145 ppb of TCA, but this value decreased by about 35 ppb every 15 minutes for 45 minutes and then the decline was more gradual. As mentioned previously, the volume of water in the lateral between the

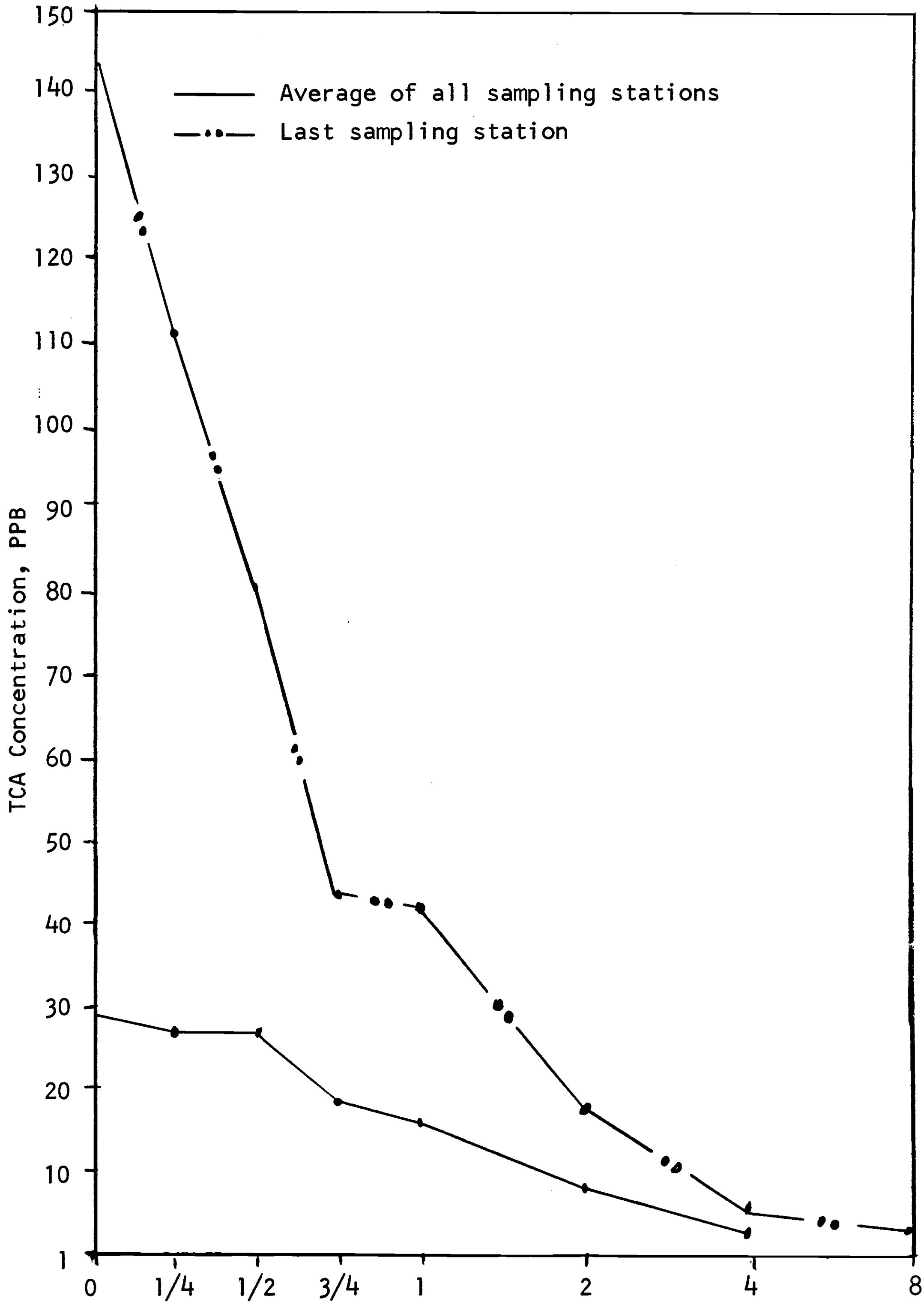

FIGURE 19. The concentration of TCA in irrigation water during the first 8 hours that water flowed through Lateral 4.

11.3 and 14.5-kilometer station was slightly greater than the volume normally carried during the irrigation season. Therefore, it extended above the normal waterline and removed a larger quantity of TCA than was possible at the more upstream sites. Also, the velocity was much greater and reduced or eliminated the dilution effect that was evident in other sections of Lateral 4 as well as in the other laterals.

Residues were present in the water for a longer period of time in Lateral 4 than in either of the other laterals sampled. Eight hours after the first water flowed past the 14.5-kilometer station, there were still 2.7 ppb TCA in the water and after 24 hours there were 1.6 ppb. After 48 hours, no TCA could be detected (Appendix Table 7).

Levels of TCA present in the three laterals sampled were not considered to be of practical significance in irrigation water. The maximum concentration detected in the three laterals was only 225 ppb and this concentration was present for only a very short time (less than 30 minutes). A concentration of 225 ppb is equal to only 908 grams of TCA per hectare-meter of water. The highest calculated average concentration during the first 4 hours that water flowed through the laterals was 47 ppb. Many of our irrigated soils will not absorb more than about 0.63 cm of water per hour. Based on these values, only 2.54 cm of water could be applied on 1 hectare during the 4-hour period that residues were perceptible. Thus, using the highest average concentration as a base value (47 ppb), only 11.2 grams of TCA would be contained in the water applied to 1 hectare. If the highest concentration measured in the three laterals (225 ppb) is used as a base value for the entire 4-hour period, 54 g/ha of TCA would be deposited on a field in a 4-hour period.

No work has been reported concerning the effect of TCA in irrigation water on crops irrigated with such water. However, Bruns and Dawson (15) found that 560 g/ha of dalapon, an herbicide closely related to TCA, did not reduce the yield of corn or rutabagas when applied to the crops in 7.2 hectare-centimeters of water. In later studies, Bruns (14) determined the residues of dalapon in corn and beans after they were irrigated with 5 hectare-centimeters of water that contained the equilavent of 560 g/ha of dalapon. The maximum residues that resulted from such treatments were 5.8 and 6.3 ppm in beans and corn, respectively. Residues as high as 30 ppm of dalapon are permitted in some vegetable crops. If TCA in irrigation water affected corn, rutabagas, and beans to the same extent as dalapon, approximately 50 times more TCA would be required to reach the no effect level (560 g/ha) than was present in any of the laterals studied.

SUMMARY AND CONCLUSIONS

Four field and greenhouse studies were conducted to gain a better understanding of the development and variations in reed canarygrass, an important ditchbank weed in the Pacific Northwest and Rocky Mountain States.

Mature reed canarygrass seed collected from plants growing along an irrigation canal was subjected to germination tests immediately after harvest, or after storage under six different environmental conditions for periods of time up to 1 year. Six-hundred seeds were removed from each storage condition at 1-month intervals and subjected to germination tests. All germination tests were conducted at alternating termperatures of 20 and 30C, with illumination at the higher temperature.

Ninety-nine percent germination was obtained immediately after harvest and 92 to 99 percent of the seeds stored in damp sand or stored dry at 1C and in damp sand at 23C germinated on each sampling date. The germination of seeds stored dry at 23C decreased gradually from 97 percent after 1 month in storage to 70 percent after 9 months. After 10 and 11 months in dry storage at 23C the germination percentage dropped to 5 percent or less and then it ascended to 59 percent after 12 months. At least 70 percent of the seed stored dry at air temperatures germinated on each of the sampling dates. Many of the seeds stored in damp sand at air temperatures germinated in storage, but at least 26 percent of them did not germinate until they were placed in the germinator.

The results of this study agree with the work of Vose (59) and Colbry (18). They also show that seeds maintained in a moist condition at constant temperatures of 1 and 23C do not germinate under such conditions, but retain their viability for a period of at least 1 year.

Reed canarygrass seedlings grown in the greenhouse under a 12-hour photoperiod and at alternating temperatures of approximately 16 and 25C, began to develop rhizomes 26 days after the seedlings emerged from the soil surface. Sixteen weeks after emergence, there were an average of 48 rhizomes per plant. The rhizomes grew downward to a depth of only 2 to 5 cm before they turned upward to form a new shoot and their maximum length was 6.5 cm. Roots penetrated to a depth of 60 cm (the maximum depth of the culture vessel) 10 weeks after the seed was planted. Thirteen weeks after emergence, the plants began to flower and they were in full-bloom 2 weeks later.

Seedlings of most rhizomatous perennial grasses are relatively easy to kill up to the time that rhizomes form, but after rhizomes form they become increasingly difficult to control. Emergence of reed canarygrass seedlings along irrigation ditchbanks is extremely irregular, because of large differences in soil temperature, seed burial depth, and soil moisture. It is highly unlikely that the entire seedling population could be controlled with a single herbicide applied before some of the seedlings that emerged early in the season developed rhizomes. Preventation of seed production by mechanical or chemical methods appears to be the most appropriate solution to this problem.

The vertical distribution of reed canarygrass rhizome and tiller buds that produced emergent shoots was determined on established plants in the field. During a 4-month period, 88 to 95 percent of the shoots originated from buds located in the upper 5 cm of soil. On four observation dates, 4.7 to 9.5 percent of the shoots were produced from buds located 5 to 10 cm below the soil surface. Less than 1 percent of the total shoots emerged from buds located 10 to 15 cm or 15 to 20 cm beneath the soil surface and no shoots emerge from depths greater than 20 cm.

The distribution of the reproductive buds suggests that a root-absorbed herbicide that does not translocate readily in a basipetal direction would have to be leached (or incorporated) to a depth of 20 cm in order to be effective for the control of established reed canarygrass. Mechanical incorporation of herbicides on most ditchbanks is impossible and precipitation in many irrigated areas of the West would be insufficient to leach a number of root-absorbed herbicides to this depth.

The vegetative and reproductive characteristics of reed canarygrass plants collected from six different canals in four states varied widely when the plants were propagated in a garden at Prosser, Washington. Plant height at the time of flower emergence and at full maturity ranged from 84 to 159 cm, and from 171 to 217 cm, respectively. Other characteristics that differed significantly were the color, length, width, and posture of leaves, the number and diameter of stems per plant, the rate of spread by rhizomes, the length of panicles, and seed weights. Ninety-seven to 99 percent of the seed produced by all plants germinated within 16 days after it was harvested.

These data clearly show that there are a number of "strains" of reed canarygrass on the ditchbanks of irrigation projects in the Pacific Northwest and Rocky Mountain States. Ecological and physiological studies should be conducted to determine if these morphological differences have any bearing on the control and/or management of the species on ditchbanks. It appears that certain "strains" that spread by rhizomes nearly twice as fast as other "strains" would be the most competitive. Also, if the "strains" respond differently to a given herbicide, as has been indicated, alternate control programs should be developed accordingly.

The total available carbohydrates in the roots and rhizomes of established reed canarygrass plants was determined on 23 dates during a 19-month period. The effect of repeated treatments of dalapon at 22 kg/ha, amitrole-T at 4.5 kg/ha, and paraquat at 1.1 kg/ha on the carbohydrate status in the roots and rhizomes was also determined on 15 of these dates. Carbohydrates were extracted with a 0.2N sulfuric acid solution and quantitated by the anthrone method as modified by Kahan (36)

The level of carbohydrates in the roots and rhizomes of untreated plants fluctuated between 26 and 33 percent of the total dry matter on 20 of the 23 sampling dates. According to Duncans' Multiple Range Test, a minimum mean difference of 6.2 percent was required for significance at the 5 percent level of probability. Therefore, there were few statistical differences between sampling dates. Carbohydrates tended to increase gradually each year during the fall months and accounted for 42 percent of the total solids in October of one year.

The level of carbohydrates in the roots and rhizomes of reed canarygrass treated with the three herbicides was not significantly lower than those in untreated plants until 2 months after the treatments were applied. At the end of the first season (October) carbohydrates in plants treated with a single application of amitrole-T and dalapon were 28 and 24 percent lower than in untreated plants, respectively. Five repeated applications of paraquat reduced the carbohydrates 50 percent during the same period. However, by May of the following year, there were no differences between the levels of carbohydrates in any of the plants. Moreover, carbohydrate levels in October of the second year were no different from those present in October of the first year even though two repeated applications of amitrole-T or dalapon and five repeated applications of paraquat were applied between May and September of the second year.

None of the herbicides reduced the stand of reed canarygrass appreciably during the 19-month period. Apparently, newly emerged shoots of reed canarygrass produced sufficient photosynthate to sustain rapid vegetative growth and replenish the reserves in the rhizomes and roots very early in the season. Methods of weed control that depend upon starvation of the rhizome-root system for success would have to be applied more frequently and later in the fall and/or earlier in the spring than they were in this study.

Three field experiments were conducted in an attempt to develop more effective and economical methods of controlling established reed canarygrass on irrigation ditchbanks without denuding the treated areas. Dalapon and TCA, applied to the soil after reed canarygrass topgrowth was burned off or to the partially dead foliage in November, at rates of 22 to 88 kg/ha, were the most effective and desirable treatments found. TCA was more effective than dalapon at equal rates of application, and dalapon was more effective as a dormant treatment than as a postemergence treatment applied at any of four different growth stages.

Redtop and reed canarygrass seedlings, as well as a host of broadleaf plants, became established on the treated areas during the year after treatment with TCA or dalapon. Reed canarygrass returned to dominance if the seedlings were not controlled. However, when the reed canarygrass seedlings were temporarily controlled with a single post-emergence application of amitrole-T at 4.5 kg/ha or dalapon at 22 kg/ha, redtop became dominant and prevented or retarded the reinvasion of the treated areas by reed canarygrass for at least two years.

The herbicide costs for a program utilizing TCA as a dormant treatment in two successive years and a postemergence treatment of dalapon or amitrole-T during the intervening year would be about $12 and $14 per kilometer of canal per year, respectively. The herbicide costs of current control practices range from about $25 to $31 per kilometer per year. Studies need to be conducted for several years on the same area to determine the rate at which reed canarygrass reinvades ditchbanks treated in such a manner and to develop long-range management programs. Also, this combination of treatments needs to be evaluated under a wider range of edaphic and climatic conditions than was possible in this study.

The levels of TCA in irrigation water were determined following November applications of the herbicide for reed canarygrass control on ditchbanks. Both banks of the dewatered laterals were treated at a rate of 82 kg/ha and the first water that flowed through them the following spring was sampled at several locations and for various periods of time up to 48 hours. TCA residues were determined by electron capture gas chromatography.

The maximum and average concentrations of TCA in irrigation water increased as the water flowed from the upper to the lower ends of the laterals. The maximum concentration of TCA in water from laterals

4, 8.4, and 14.5 kilometers in length were 104, 225, and 145 ppb, respectively. The average residue levels at the downstream ends of the laterals during the first 4 hours of waterflow were 36, 47, and 34 ppb, respectively. No TCA could be detected 8, 8, and 48 hours after the first flow of water through laterals 4, 8.4 and 14.5 kilometers long, respectively.

The number and height of check dams appeared to influence the time when the maximum residue level was detected. In the three laterals studied, the maximum concentration was detected within the first 60 minutes of waterflow. Also, the volume of water in relation to the size of the channel affected the maximum residue level and the total length of time that the residue was detectable.

It is doubtful that treatment of canal banks with TCA at rates up to 82 kg/ha in the fall would contaminate irrigation water sufficiently to injure or contaminate crop plants with illegal herbicide residues. However, data to support this hypothesis should be obtained. Also, the dissipation rate of TCA in ponded water at various temperatures should be ascertained in the event that the herbicide is not permitted in water used for any purpose.

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APPENDIX

APPENDIX TABLE 1. Analysis of variance summary tables for ten vegetative and seed characteristics of six reed canarygrass selections.

Source	d.f.	S.S.	M.S.	F
1. Height at the time the first flowers emerged				
Replications	3	107.8	35.9	4.05*
Selections	5	17,312.9	3,462.6	390.64**
Error	15	132.9	8.9	
Total	23	17,553.6		

C.V. = 2.41; minimum signif. diff. at 0.05 = 4.48

Source	d.f.	S.S.	M.S.	F
2. Height on June 8, 1970				
Replications	3	0.009	0.003	1.75 N.S.
Selections	5	0.502	0.100	56.41**
Error	15	0.027	0.002	
Total	23	0.538		

C.V. = 2.23; minimum signif. diff. at 0.05 = 0.06

Source	d.f.	S.S.	M.S.	F
3. Clone basal area				
Replications	3	14,039	4,679.7	.979 N.S.
Selections	5	290,308	58,061.6	12.149**
Error	15	71,685	4,779.0	
Total	23	376,032		

C.V. = 16.745; minimum signif. diff. at 0.05 = 1040

Source	d.f.	S.S.	M.S.	F
4. Number of stems per plant				
Replications	3	19,758	6,586	2.01 N.S.
Selections	5	115,073	23,015	7.02**
Error	15	49,171	3,278	
Total	23	184,002		

C.V. = 18.011; minimum signif. diff. at 0.05 = 86.18

Source	d.f.	S.S.	M.S.	F
5. Stem diameter				
Replications	3	3.477	1.159	8.187**
Selections	5	28.513	5.703	40.286**
Error	15	2.123	0.141	
Total	23	34.113		

C.V. = 6.253; minimum signif. diff. at 0.05 = .566

APPENDIX TABLE 1 (Continued)

Source	d.f.	S.S.	M.S.	F
6. Maximum leaf length				
Replications	3	1.410	.470	0.297 N.S.
Selections	5	189.145	37.829	23.937**
Error	15	23.705	1.580	
Total	23	214.260		

C.V. = 3.736; minimum signif. diff. at 0.05 = 1.89

Source	d.f.	S.S.	M.S.	F
7. Maximum leaf width				
Replications	3	6.116	2.039	2.21 N.S.
Selections	5	76.423	15.285	16.58**
Error	15	13.825	.922	
Total	23	96.364		

C.V. = 4.570; minimum signif. diff. at 0.05 = 1.44

Source	d.f.	S.S.	M.S.	F
8. Panicle length				
Replications	3	1.891	0.630	0.82 N.S.
Selections	5	92.882	18.576	24.24**
Error	15	11.496	0.766	
Total	23	106.269		

C.V. = 4.17; minimum signif. diff. at 0.05 = 1.32

Source	d.f.	S.S.	M.S.	F
9. Weight per 1000 seeds				
Replications	3	0.0053	0.00178	0.796 N.S.
Selections	5	0.6240	0.12481	55.900**
Error	15	0.0335	0.00223	
Total	23	0.6628		

C.V. = 4.707; minimum signif. diff. at 0.05 = .071

Source	d.f.	S.S.	M.S.	F
10. Germination percentage of seed after 7 days in germinator				
Replications	3	83.458	27.819	1.07 N.S.
Selections	5	2,663.708	532.742	20.50**
Error	15	389.792	25.986	
Total	23	3,136.958		

C.V. = 6.613; minimum signif. diff. at 0.05 = 7.67

APPENDIX TABLE 1 (Continued)

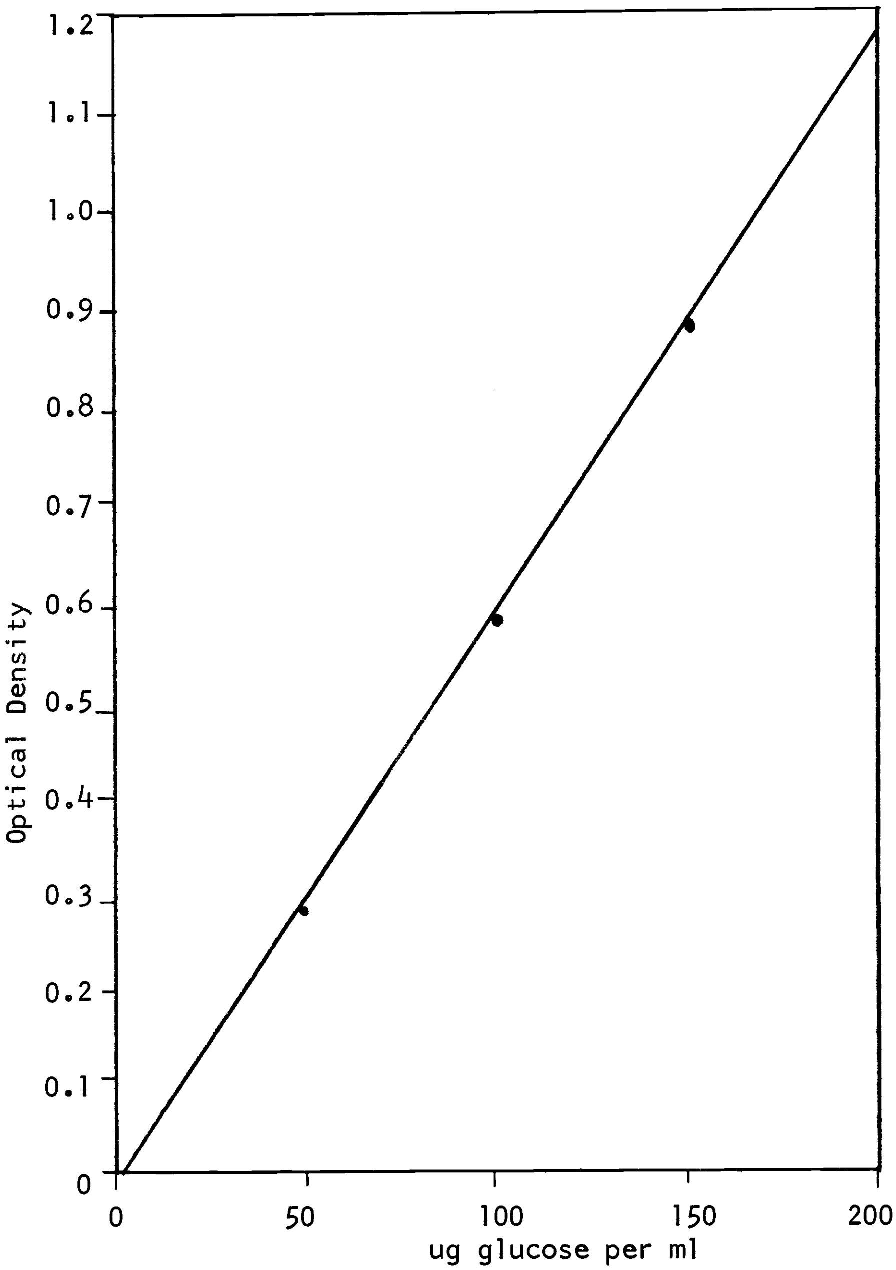
Source	d.f.	S.S.	M.S.	F
11. Germination percentage of seed after 16 days in germinator				
Replications	3	9.125	3.042	.989 N.S.
Selections	5	18.708	3.742	1.217 N.S.
Error	15	46.125	3.075	
Total	23	73.958		

C.V. = 1.781

** Indicates an F test that exceeds the 0.01 level of probability.

* Indicates an F test that exceeds the 0.05 level of probability.

N.S. Not significant.



APPENDIX FIGURE 1. Standard curve for glucose using the modified anthrone reagent.

APPENDIX TABLE 2. Analysis of variance summary table for percent total available carbohydrates and total dry matter in the rhizomes and roots of untreated reed canarygrass in 1967 and 1968.

Source	d.f.	S.S.	M.S.	F
1. Total carbohydrates:				
Replications	2	13.001	6.504	.458 N.S.
Dates	22	994.846	45.220	3.187**
Error	44	624.217	14.187	
Total	68	1,632.064		
C.V. = 12.43; minimum signif. diff. at 0.05 = 6.20				
2. Total dry matter:				
Replications	2	4.826	2.413	.711 N.S.
Dates	22	222.817	10.128	2.983**
Error	44	149.387	3.395	
Total	68	377.030		
C.V. = 12.57; minimum signif. diff. at 0.05 = 3.03				

** Indicates an F test that exceeds the 0.01 level of probability.

N.S. Not significant.

APPENDIX TABLE 3. Analysis of variance summary table for the effect of sampling date on the percent of total available carbohydrates in the rhizomes and roots of reed canarygrass.

Source	d.f.	S.S.	M.S.	F
1. Untreated				
Replications	2	2.598	1.299	0.08 N.S.
Dates	14	752.599	53.757	3.52**
Error	28	427.076	15.253	
Total	44	1,182.273		
C.V. = 13.27; minimum signif. diff. at 0.05 = 6.52				
2. Amitrole-T				
Replications	2	12.718	6.359	0.65 N.S.
Dates	14	841.175	60.084	6.12**
Error	28	274.930	9.819	
Total	44	1,128.823		
C.V. = 13.08; minimum signif. diff. at 0.05 = 5.23				
3. Dalapon				
Replications	2	3.037	1.518	0.38 N.S.
Dates	14	945.116	67.508	16.72**
Error	28	113.042	4.037	
Total	44	1,061.465		
C.V. = 8.45; minimum signif. diff. at 0.05 = 3.36				
4. Paraquat				
Replications	2	24.802	12.401	1.60 N.S.
Dates	14	818.634	58.474	7.57**
Error	28	216.258	7.723	
Total	44	1,059.694		
C.V. = 13.11; minimum signif. diff. at 0.05 = 4.64				

** Indicates an F test that exceeds the 0.01 level of probability.

N.S. Not significant.

APPENDIX TABLE 4. Analysis of variance summary table for the effects of treatments on the percent of total available carbohydrates in the rhizomes and roots of reed canarygrass within sampling dates in 1967 and 1968.

Source	d.f.	S.S.	M.S.	F
May 15, 1967				
Replications	2	7.480	3.740	1.46 N.S.
Treatments	3	18.305	6.101	2.39 N.S.
Error	6	15.318	2.553	
Total	11	41.103		
C.V. = 5.42				
May 22, 1967				
Replications	2	16.610	8.305	1.36 N.S.
Treatments	3	24.178	8.059	1.32 N.S.
Error	6	36.715	6.119	
Total	11	77.503		
C.V. = 9.53				
May 29, 1967				
Replications	2	16.091	8.045	0.86 N.S.
Treatments	3	41.181	13.727	1.46 N.S.
Error	6	56.257	9.376	
Total	11	113.529		
C.V. = 11.92				
June 5, 1967				
Replications	2	.095	.048	0.01 N.S.
Treatments	3	115.343	38.448	10.43**
Error	6	22.113	3.685	
Total	11	137.551		
C.V. = 6.91; minimum signif. diff. at 0.05 = 3.81				
June 13, 1967				
Replications	2	15.616	7.808	0.70 N.S.
Treatments	3	66.187	22.062	1.98 N.S.
Error	6	66.799	11.133	
Total	11	148.602		
C.V. = 13.57				

APPENDIX TABLE 4 (Continued)

Source	d.f.	S.S.	M.S.	F
July 7, 1967				
Replications	2	6.958	3.479	0.68 N.S.
Treatments	3	182.795	60.932	11.91**
Error	6	30.687	5.114	
Total	11	220.440		

C.V. = 9.74; minimum signif. diff. at 0.05 = 4.50

Source	d.f.	S.S.	M.S.	F
August 7, 1967				
Replications	2	10.600	5.300	1.03 N.S.
Treatments	3	193.480	64.493	12.58**
Error	6	30.747	5.124	
Total	11	234.827		

C.V. = 11.86; minimum signif. diff. at 0.05 = 4.50

Source	d.f.	S.S.	M.S.	F
September 7, 1967				
Replications	2	0.659	0.330	0.06 N.S.
Treatments	3	455.741	151.914	27.81**
Error	6	32.773	5.462	
Total	11	489.173		

C.V. = 10.29; minimum signif. diff. at 0.05 = 4.64

Source	d.f.	S.S.	M.S.	F
October 6, 1967				
Replications	2	75.208	37.604	5.78*
Treatments	3	396.780	132.260	20.33**
Error	6	39.031	6.505	
Total	11	511.019		

C.V. = 10.52; minimum signif. diff. at 0.05 = 5.08

Source	d.f.	S.S.	M.S.	F
May 8, 1968				
Replications	2	85.218	42.609	2.95 N.S.
Treatments	3	14.676	4.892	0.34 N.S.
Error	6	86.624	14.437	
Total	11	186.518		

C.V. = 13.35

Source	d.f.	S.S.	M.S.	F
June 6, 1968				
Replications	2	6.591	3.295	0.33 N.S.
Treatments	3	132.156	44.052	4.36 N.S.
Error	6	60.630	10.105	
Total	11	199.377		

C.V. = 12.90

APPENDIX TABLE 4 (Continued)

Source	d.f.	S.S.	M.S.	F
July 9, 1968				
Replications	2	7.676	3.838	0.76 N.S.
Treatments	3	145.095	48.365	9.58**
Error	6	30.288	5.048	
Total	11	183.059		
C.V. = 9.42; minimum signif. diff. at 0.05 = 4.50				
August 8, 1968				
Replications	2	7.734	3.867	0.29 N.S.
Treatments	3	139.527	46.510	3.51 N.S.
Error	6	79.372	13.229	
Total	11	226.633		
C.V. = 17.32				
September 5, 1968				
Replications	2	20.494	10.247	0.46 N.S.
Treatments	3	377.200	125.733	5.68*
Error	6	132.726	22.121	
Total	11	530.420		
C.V. = 24.68; minimum signif. diff. at 0.05 = 9.3				
October 9, 1968				
Replications	2	7.078	3.539	0.32 N.S.
Treatments	3	846.135	282.045	25.97**
Error	6	65.167	10.861	
Total	11	918.380		
C.V. = 11.39; minimum signif. diff. at 0.05 = 6.57				

** Indicates an F value that exceeds the 0.01 level of probability.

* Indicates an F value that exceeds the 0.05 level of probability.

N.S. Not significant.

APPENDIX TABLE 5. Levels of TCA in the Campbell Lateral following treatment of both banks with TCA at 82 kg/ha in November, 1969. Water samples collected at the time first water was turned into the lateral in the spring, April 1, 1970. All data are averages of three replications.

Station No	Kilometers downstream 1/	Concentration of TCA, PPB Hours after first flow of water									
		0	1/4	1/2	3/4	1	2	4	8	24	48
1	0	0.0	-	-	-	0.1	0.2	0.1	0.1	0.0	-
2	0.8	0.8	1.4	3.3	15.8	27.0	4.0	1.8	-	-	-
3	1.6	1.1	7.0	55.1	75.5	58.7	5.8	1.1	-	-	-
4	2.4	10.1	24.7	65.5	77.4	67.8	10.8	1.4	-	-	-
5	3.2	28.5	60.8	66.9	91.5	77.8	19.2	2.3	-	-	-
6	4.0	11.1	31.7	67.5	78.6	103.6	20.9	3.3	0.2	0.0	0.0

1/ Downstream from upper end of treated area.

APPENDIX TABLE 6. Levels of TCA in the East Lateral following treatment of both banks with TCA at 82 kg/ha in November, 1969. Water samples collected at the time first water was turned into the canal in the spring, March 25, 1970. All data are averages of three replications.

Station No. 1/	Kilometers downstream 2/	Concentration of TCA, PPB Hours after first flow of water									
		0	1/4	1/2	3/4	1	2	4	8	24	48
1	0	0.7	-	-	-	-	0.2	0.9	0.6	-	-
2	.8	0.4	57.3	46.8	12.7	4.3	1.8	0.5	-	-	-
3	1.6	1.8	65.1	72.2	28.1	21.3	4.2	0.6	-	-	-
4	3.2	28.8	40.8	45.4	107.6	19.9	2.7	1.9	-	-	-
5	4.8	80.0	177.3	142.5	49.4	39.9	5.8	2.3	-	-	-
6	6.4	91.3	187.3	82.3	35.4	17.2	5.6	2.3	-	-	-
7	8.4	144.1	225.4	140.1	78.7	44.3	24.1	5.4	0.7	0.0	0.0
8	7.4	66.5	146.0	119.3	70.6	40.6	2.5	1.0	-	-	-
9	8.4	36.5	74.7	90.7	56.5	39.5	14.0	0.7	-	-	-

1/ Station Nos. 8 and 9 were located on an untreated lateral that branched off the East Lateral at Station No. 6.

2/ Downstream from upper end of treated area.

APPENDIX TABLE 7. Levels of TCA in Lateral No. 4 following treatment of both banks with TCA at 82 kg/ha in November, 1969. Water samples collected at the time first water was turned into the lateral in the spring, March 20, 1970. All data are averages of three replications.

Station No.	Kilometers downstream 1/	Concentration of TCA, PPB Hours after first flow of water									
		0	1/4	1/2	3/4	1	2	4	8	24	48
1	0	0.4	-	-	-	-	-	0.9	0.0	0.0	0
2	0.8	0.8	5.8	2.0	1.8	1.6	0.9	0.6	-	-	-
3	1.6	1.3	1.4	4.6	2.4	2.8	1.9	0.6	-	-	-
4	4.8	11.3	11.2	10.3	6.6	7.3	4.9	1.2	-	-	-
5	8.0	8.4	13.2	17.4	26.2	12.1	5.6	1.9	-	-	-
6	11.3	7.4	18.9	47.7	30.4	28.4	15.6	4.2	-	-	-
7	14.5	145.1	11.6	80.3	43.4	42.1	17.3	4.8	2.7	1.6	0.0

1/ Downstream from upper end of treated area.