WINTER SURVIVAL OF BERMUDAGRASSES (*CYNODON* SP.) AS INFLUENCED BY DEACCLIMATION, LOW TEMPERATURES, AND DORMANCY PERIODS

by

David Robert Chalmers

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APPROVED:

R. E. Schmidt
Dr. R. E. Schmidt, Chairman

Thos B. Hutcheson Jr.
Dr. T. B. Hutcheson, Jr.

R. E. Blaser
Dr. R. E. Blaser

D. D. Wolf
Dr. D. D. Wolf

Lawrence D. Moore
Dr. L. D. Moore

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INTRODUCTION

Cold winter temperatures of the northern extremity, where semi-tropical grasses are adapted in the United States, frequently are lethal to bermudagrasses (Cynodon spp.) used for turf. It is, therefore, imperative that cultivars which are cold hardy and persist under long dormancy periods be identified and used for turf in this area.

Certain bermudagrass cultivars develop some resistance to low temperatures through acclimation processes (Reeves et al., 1970). 'Tifgreen' bermudagrass has survived lower artificial freezing temperatures (during winter) than has 'Tifdwarf' bermudagrass (Davis and Gilbert, 1970). Artificial freezing tests have been used to distinguish between hardy and non-hardy bermudagrass cultivars, giving results comparable to those obtained in field plot tests (Dunn and Nelson, 1974). These researchers also showed that bermudagrass stolons and rhizomes exhibit reductions in cold hardiness during late winter.

Cold hardiness levels are not static, varying with season, temperature, day length, maturity, moisture content, mineral nutrition, and physiological age (Stushnoff, 1972). Maximum hardiness in bermudagrass appears to occur during early winter but declines severely during late winter (Dunn and Nelson, 1974). Studies with other grasses show similar trends. Cold resistance of orchardgrass in West Virginia increased during the fall, leveling off during December and January, then slowly decreased during February and quickly through March (Howell and Jung, 1965).

Deacclimation has also received attention as a possible cause of winter injury. With St. Augustinegrass (Stenotaphrum secundatum) (Reeves and McBee, 1972) and with centipedegrass (Eremochloa ophiuroides) (Johnston and Dickens, 1976), cold tolerance was lost within a few days of exposure to warm temperatures. Little work however has been reported on the deacclimation of dormant bermudagrass.

There has been speculation on possible reductions of cold tolerance of plants from late winter warming periods. It has been suggested that low carbohydrate reserves in late winter could result in an inability of plants to reharden in response to low temperatures following a warming period (Smith, 1964). Rapidly falling temperatures may not allow the plant time to reacclimate.

Experiments for this thesis were conducted in the field and laboratory using selected bermudagrasses. The objectives of these experiments were as follows:

1. To study the effect of low temperature on deacclimated 'Tifgreen' bermudagrass.

2. To determine the influence of dormancy periods following exposure to deacclimating conditions and subsequent low temperatures.

3. To study the survival of selected bermudagrasses when frozen in a late-winter dormant condition and in the non-dormant state.

4. To ascertain the spring recovery of bermudagrasses as influenced by traffic imposed prior to and during winter dormancy of bermudagrass.

5. To study the winter survival of selected recently established bermudagrasses.

LITERATURE REVIEW

Low temperature has been suggested to be the most important parameter in limiting plant distributions (Parker, 1963). However the winter survival of plants is complex and often confounded by many interacting factors (Olien, 1967). It should be noted that injuries caused by low temperatures are not restricted to temperatures below freezing. Tropical and subtropical plants and plant parts of certain temperate species may be injured by chilling temperatures ranging from just above freezing to 10 or 12C (Lyons, 1973). The literature reviewed below concentrates on certain aspects of subfreezing stress.

Cold Tolerance: Ice Formation

There is a high positive correlation between ice formation in plants and subsequent injury (Dexter, 1956; Smith, 1964). Ice formation occurs inside (intracellular) or outside (extracellular) the cell. Intracellular ice formation is nearly always fatal whereas plants vary in their ability to tolerate the formation of extracellular ice (Levitt, 1972). Siminovitch and Briggs (1949) found that the formation of ice crystals occurs extracellularly if temperature decreases are slow enough to allow cellular water to diffuse to extracellular crystalization sites. If freezing is rapid many small disruptive ice crystals form intracellularly. This prevents water migration to extracellular sites of ice crystal growth and results in possible mechanical damage (Burke et al., 1976). Intracellular freezing injury occurs in tender plants unable to acclimate, in hardy

plants before they acclimate, and in certain tissues of hardy species which avoid freezing until the killing point (Burke et al., 1976).

Many factors can alter freezing processes and subsequent injury. Sprague (1955) found that the rapid freezing or thawing of ladino clover (Trifolim repens L.) and alfalfa (Medicago sativa L.) caused severe injury as compared with slow freezing or thawing. In addition to freezing and thawing rates, the absolute temperature at which a plant is killed is affected by the hardiness level of the plant, the number of times frozen and the post thawing treatment (Beard, 1973). Ahring and Irving (1969) reported that as the lethal temperature for bermudagrass is approached, an increase in the length of exposure to cold results in increased injury.

Difference in moisture content in hardy tissues also influence freezing and relative cold tolerance (Mayland and Cary, 1970; Metcalf et al., 1970). Winter wheat is often injured when cold weather is followed by a midwinter thaw provided the crown tissues are high in moisture (Olien, 1967). Tumanov et al., (1969), concluded that well hardened winter wheat plants survived better than slightly hardened plants due to the water-retention capacity of cells, which restricted available water for ice crystal growth. At any given temperature, a small percentage change in crown moisture results in large differences in the crown survival of wheat and barley (Metcalf et al., 1970). Gusta et al., (1975) attributed survival differences between hardy and tender winter wheat cultivars as being most related to total plant water (g water/dryweight) and percent of total water frozen. Hardy

winter wheat plants had less total water present than tender cultivars and were able to survive a much higher proportion of water frozen.

Cold Tolerance: Acclimation and Deacclimation

Acclimation or hardening is the process whereby plants sensitive to low temperature become resistant (Weiser, 1970). Deacclimation is the reverse process. Acclimated plants are able to prevent, decrease, or repair the strain caused by low temperature stresses (Levitt, 1972). Increased cold hardiness often is preceded by physiological changes which occur within the protoplasm of the cells during favorable environmental conditions (Dexter, 1956; Levitt, 1956; Parker, 1963; Alden and Hermann, 1971; and Levitt, 1972). Thorough reviews on this subject have been published by Alden and Hermann (1971) and Levitt (1972).

Environmental conditions affect the ability of plants to acclimate, thereby affecting the degree of cold tolerance achieved. Day length and temperature appear to be major factors in the development of cold hardiness (Johnston and Dickens, 1976; Aronsson et al., 1976). Maximum increases in hardiness usually occur as days shorten and temperatures decrease (Smith, 1964; Beard, 1973; Aronsson et al., 1976).

Stushnoff (1972) suggested that the components of acclimation and deacclimation are associated with a) time of development of cold tolerance; b) rate of development of cold tolerance; c) intensity of cold tolerance developed; d) retention of cold tolerance; e) onset of loss of cold tolerance; f) rate of loss of cold tolerance; and g) ability to regain cold tolerance. Other workers also investigated the level of cold hardiness of plants during the winter period. Beard

(1973) found maximum cold hardiness of turfgrasses generally to occur during early winter, followed by a slight decrease in February, with severe reductions in low temperature hardiness in late winter. Similarly, Davis and Gilbert (1970) using LT_{50}'s (low temperature which caused a 50 percent reduction in growth when compared to unfrozen checks) achieved LT_{50}'s for bermudagrass (Cynodon spp.) of -2.2C in September, -8.1C in February, -5.6C in April, and -2.5C in May. Other studies with grasses show similar trends of hardiness during winter (Dunn and Nelson, 1974; Howell and Jung, 1965).

The loss of cold hardiness occurs at dates other than late winter (Dexter, 1941; Edgerton, 1954; Reeves and McBee, 1972). Factors which induce rapid active growth generally cause a decrease in cold resistance (Levitt, 1972). The decreasing rates of cold resistance depend on the degree of plant hardiness (Laude, 1937a). Warm temperatures decrease hardiness; the duration of exposure as well as the temperature affects the amount of hardiness lost (Smith, 1964). Upon exposure to alternating warm and cold temperatures alfalfa and winter wheat dehardened and rehardened if growth did not occur (Dexter, 1941). Edgerton (1954) exposed peach twigs in the rest period to 65°F for as long as 7 days. Freezing tests showed 4 days exposure to 65°F had little or no effect on hardiness, while exposure for 7 days resulted in considerable loss of hardiness. Reeves and McBee (1972), investigating the exposure of nondormant St. Augustinegrass to warm temperatures, found loss of cold hardiness within a few days.

Winter survival is often unexplainable. Injury to plants can be mild during a severe winter and severe during a mild winter (Stushnoff,

1972). A plant species often survives winter conditions when air temperatures are below its tissue killing point. Air temperature, however, is not an indicator of the plant environment per se. Official temperature records taken at 1.37 m (4 1/2 feet) are of limited value when evaluating the causes of winter injury (Kinbacher and Jensen, 1959). Sprague et al., (1954) found the microclimate layer below 1.22 m to have a more rigorous fluctuation of temperatures than the macroclimate layer above it. Temperature extremes are greatest at the soil surface generally being higher during daytime and lower at night than at 1.37 m. Air temperatures in canopies that alternate above and below freezing can be very damaging to plants (Smith, 1964).

Snow cover moderates surface temperature fluctuations to within a few degrees of freezing (Kinbacher and Jensen, 1959). The insulating effect of soil and canopies aid underground plant parts such as roots, rhizomes, and crowns in surviving low air temperatures (Dexter, 1956; Smith, 1964; Olien, 1967; Ahring and Irving, 1969; and Burke et al., 1976).

The injury caused by winter varies with years. Mineral nutrients are important factors in winter survival (Juska and Murray, 1974). Heavy and late applications of nitrogen in fall have been found to reduce the cold resistance of 15 turfgrasses (Carroll, 1943). Applying nitrogen up to November 1 in Rhode Island reduced the cold resistance of Kentucky bluegrass as measured by an artificial freeze test of -7C (Wilkinson and Duff, 1972). Adams and Twersky (1959) decreased winter kill of 'Coastal' bermudagrass by increasing levels of potassium

when nitrogen was held constant. Fertility variables altered the killing point of 'Tifgreen' bermudagrass by only 1 to 2C; with the greatest injury occurring at high rates of phosphorus without potassium (Reeves et al., 1970). Increasing rates of potassium decreased injury. A fertilizer ratio of 4-1-6 increased winter hardiness of 'Tifgreen' bermudagrass in North Carolina (Davis and Gilbert, 1970).

Gilbert and Davis (1971) recommend a balanced fertility program emphasizing late summer potassium applications to improve the cold resistance of 'Tifdwarf' and 'Tifgreen' bermudagrass. In testing three bermudagrass varieties in Maryland, Juska and Murray (1974) found more winter injury on plots not treated with potassium than on plots treated with potassium.

Increasing cold tolerance of plants with chemicals is not usually successful (Smith, 1964). Ruelke (1961) found spraying maleic hydrazide on Digitaria decumbens in Florida reduced winter injury by preventing growth during warm winter periods resulting in the conservation of food reserves. Karbassi et al., (1971) prevented growth depression of Digitaria decumbens exposed to 10C temperature by applying gibberellic acid. Low temperature induced discoloration was retarded to a large extent by gibberellic acid in zoysia and bermudagrass (Sachs et al., 1971). The experiment concentrated on the effect of chilling temperatures ranging from 1.5 to 10C.

The winter hardiness of 'Tifgreen' bermudagrass was found to be less when DCPA (dimethyl tetrachloroterephthalate) treatments were applied during establishment (Fullerton et al., 1970). A chemical analysis of the bermudagrass revealed increases in total nitrogen,

nitrate, amino acids, and protein from DCPA treatments indicating a less hardy condition. Coats et al., (1973) found 'Tifdwarf' bermudagrass treated with DCPA experienced a delay in spring transition (dormant to nondormant).

Cold Tolerance: Methods of Evaluation

Many methods have been proposed for evaluating winter hardiness and cold tolerance in plants. Dexter (1956) and Levitt (1972) reviewed many methods. Freezing methods include winter tests and artificial freezing. Non-freezing methods are based on the knowledge that changes in many metabolic components are correlated with increasing hardiness (Dexter, 1956; Smith, 1964; and Levitt, 1972). For example, nucleic acid, lipid, protein, and sugar quantity and/or quality have been shown to fluctuate during hardening and dehardening. However, Levitt (1972) cautions that; "past experience indicates that no one indirect measuring stock can be trusted as a measure of relative freezing resistance in all plants" and continues to state "direct freezing tests are essential for fully reliable measurements of freezing resistance, whether it is due to tolerance or avoidance." Valid criteria that determine injury or recovery from injury are essential for ascertaining harmful effects of low temperatures. Visual examinations using such parameters as percentage stand counts, percentage ground cover, and vigor have been used by many workers (Klebesadel et al., 1964; Adams and Twersky, 1959; Reeves et al., 1970; Juska and Murray, 1970; Dunn and Nelson, 1974; Rogers et al., 1975; and Johnston and Dickens, 1976).

Dexter et al., (1932) introduced a method for determination of electrical conductivity of electrolytes leached from cold injured cells. Increasing injury results in a progressive loss of electrolytes from the cell resulting in greater conductivity values of extracts. Microscopic examination of the ability of cells to plasmolyze and deplasmolyze after freezing has been discussed by Levitt (1972). Another method is the triphenyl tetrazolium chloride (TTC) test (Parker, 1953; Parker, 1963; Steponkus and Lanphear, 1967; Ahring and Irving, 1969). Test results are obtained by visual observation on the degree of tetrazolium reduction based on color.

MATERIALS AND METHODS

Experiment 1. Winter Survival of *Cynodon* sp. as Influenced by Deacclimation and Low Temperatures.

A six year old plot of 'Tifgreen' bermudagrass maintained at a 1.25 cm clipping height at Blacksburg, Virginia, was used for this research. A typic Hapludult clayey, kaolinitic, mesic family (Lodi silt loam) soil with a high content of P (271 kg/ha), a medium level of K (146 kg/ha) and a pH of 6.0 was used. These analyses were completed in the Virginia Polytechnic Institute and State University Extension Soil Testing Laboratory. Soluble nitrogen fertilizer was applied to the plot at a rate of 2.15 kg/are each growing season. Irrigation was used during the growing season to maintain plant growth.

During late winter (February, 1977) 52 plugs 15.2 cm in diameter and 8 cm deep were removed and placed in 33 x 48 x 7.6 cm metal flats with holes in the bottom for drainage. The plugs were randomized into four groups. The four groups were brought into a greenhouse and subjected to 27-13C (day-night) to simulate warm temperature periods during winter for 0, 2, 4, and 8 days. The plugs were watered daily.

Subsequently the rhizomes and stolons were separated from the plugs; rhizomes were trimmed to lengths of 2 nodes and stolons were 2.5 to 5 cm in length. The rhizomes and stolons were divided into units of 5 sprigs and placed into separate plastic bags. All 360 bags were then placed into a dark storage cooler maintained at a temperature of 2.8C ± 1.6C for a minimum of 24 hours and assigned the

factorial treatments: temperatures at +2, 0, -2, -4, and -6C for 24 hours; dark storage for 0, 45, and 90 days (2.8C ± 1.6C) before planting; 3 replications (Table 1).

Following the cooling period the bagged spriggs of each dehardening period (0, 2, 4, and 8 days) were subjected to +2, 0, -2, -4, or -6C for 24 hours in a freezer. Each treatment was calibrated to equal the low temperature of the cooling cycle. The high temperature of each cooling cycle averaged 3.7C above the treatment temperature. Following exposure to each low temperature, the samples were returned to the storage cooler (2.8 ± 1.6C) for a minimum of 24 hours to allow for gradual thawing.

One third of the samples from each temperature treatment (0 days storage) were planted in flats 24 hours after the last warming temperature treatment. The remaining samples were maintained in dark storage at 2.8C ± 1.6C and planted 45 or 90 days after the last freezing treatment. Spriggs were planted approximately 1.8 cm deep in flats filled with graded (2-.05 mm) inert lightweight (bulk density= 1.0) expanded shale product (manufactured by Weblite Corporation, Roanoke, Virginia). Samples were allowed to grow in the greenhouse for 3-4 weeks. The flats were kept moist with a mist system operating for 15 minutes 2 times per day. Percent growth from the total rhizome and stolon nodes was recorded at the end of the growth period. The treatments were replicated three times and arranged in a completely randomized design and the data were subjected to analysis of variance.

Table 1. Factorial treatment combinations imposed on stolons and rhizomes of 'Tifgreen' bermudagrass.

Deacclimation regimes 27C/13C (day/night)	Five low temperature treatments each for 24 hours	Days of storage at 2.8C
Duration days		
0, 2, 4, 8	+2, 0, -2, -4, -6	0, 45, 90

RESULTS

Experiment 1. Winter Survival of *Cynodon* sp. as Influenced by Deacclimation and Low Temperatures.

Rhizomes

Deacclimating dormant bermudagrass up to 8 days prior to freezing or near freezing temperatures produced significantly higher percent growth from node buds than when not warmed at all (Table 2). Rhizomes exposed to 2 and 4 days of warming prior to subjection to low temperatures produced 87 and 122 percent, respectively, more bud growth than for the no warming treatment. The 8 day warming treatment produced only 54 percent more growth from node buds than the unwarmed treatment.

Rhizome node buds did not survive when exposed to -4 and -6C, after deacclimation, regardless of the duration of exposure. Bud growth did not differ significantly for the other treatments, however the value for the -2C treatment tended to be lower than the +2 and 0C treatments (Table 2).

The duration of storage at 2.8C after the freezing periods significantly influenced growth of the rhizome buds (Table 2). For each 45 day increment in storage at 2.8C there was a significant decrease in percent bud growth. Rhizome development was 21 and 65 percent less after 45 and 90 days storage, respectively, than when planted only 24 hours after exposure to low temperatures.

Stolons

The duration of deacclimation and subsequent low temperature treatment combinations had interacting effects on growth of stolon node buds.

Table 2. Percent growth from rhizome buds after subjection to four durations of deacclimation and subsequent exposures to three low temperature treatments and three periods storage at 2.8C.

	Days deacclimation at 27C/13C (day/night temperatures)				
Temperatures	0	2	4	8	Avg.
C	% Growth				
	Storage period - 0 day				
+2	53	74	71	58	64
0	64	71	76	55	66
-2	3	71	54	56	46
Avg.	40	72	67	56	59x†
	Storage period - 45 days				
+2	40	61	75	58	58
0	33	50	57	59	50
-2	3	30	52	38	30
Avg.	26	47	61	51	46y
	Storage period - 90 days				
+2	6	21	43	13	21
0	25	44	65	16	37
-2	0	4	12	0	4
Avg.	10	23	40	10	21z
Grand Avg.	25c	47ab	56a	39b	

	Temperature		
	+2	0	-2
Grand Avg.	48A	51A	27B

Values with a letter in common do not differ significantly at the 5% level.

†Avg. compared between storage periods.

Stolon node buds did not survive the -4 or -6C temperatures after deacclimation. Generally bud growth was inversely proportional to the length of deacclimation period.

At storage day 0, growth from dormant buds was significantly reduced only for plants exposed to 8 days of deacclimating temperatures while significant reduction in growth was obtained after 4 days deacclimation when the stolon node buds were stored for 45 and 90 days.

There was a significant interaction between the temperature and storage treatments. Increasing the length of the storage period from 0 to 90 days increased the injury caused by reductions in temperature (Table 3). At storage day 0 growth from dormancy was not significantly influenced by temperature treatments. Storage periods of 45 and 90 days however, had growth from dormant buds reduced significantly with decrease of temperature from +2 to -2C. The lowest percent growth from dormant buds occurred when plants were exposed to 8 days of deacclimation and stored for 90 days regardless of temperature treatment. No growth from dormancy occurred when plants were exposed to -2C and stored for 90 days regardless of the deacclimation duration.

There was also a significant interaction between deacclimation period, temperature treatment, and storage treatment.

Table 3. Percent growth from stolon buds after subjection to four durations of deacclimation and subsequent exposures to three low temperature treatments and three periods storage at 2.8C.

	Days deacclimation at 27C/13C (day/night temperatures)				
Temperatures	0	2	4	8	Avg.
C	% Growth				
	Storage period - 0 day				
+2	37	37	32	34	35A
0	41	42	28	20	33A
-2	34	34	48	12	32A
Avg.	37a	38a	36a	22b	
	Storage period - 45 days				
+2	46	28	30	25	32A
0	28	27	13	21	22B
-2	16	23	22	3	16C
Avg.	30a	26ab	22bc	16c	
	Storage period - 90 days				
+2	28	33	10	1	18A
0	20	18	9	2	12B
-2	0	0	0	0	0C
Avg.	16a	17a	6b	1b	

Values with a letter in common do not differ significantly at the 5% level.

Avg. compared separately within storage periods.

MATERIALS AND METHODS

Experiment 2. Cold Tolerance of Five Cultivars of *Cynodon* sp.

Cold Hardiness Tests:

Six year old plots of five cultivars of *Cynodon* spp. ('Midiron', 'Tifdwarf', 'Tifgreen', 'Tifway', and 'Tufcote') arranged in a randomized block design, replicated three times, and maintained at a 2.5 cm clipping height at Newport News, Virginia, were used in this study. The soil, an Aquic Paledult: clayey, kaolinitic, thermic family (a Duplin loam), had a medium level of P (148 kg/ha), a low level of K (62 kg/ha) and a pH of 4.6. These analyses were completed in the Virginia Polytechnic Institute and State University Extension Soil Testing Laboratory. Three applications of a 2-.44-.83 ratio fertilizer was applied each growing season to supply 3.22 kg N/are. Supplemental irrigation was employed during the growing season to maintain plant growth.

Twelve plugs 10.8 cm diameter and 4.5 cm deep were removed from each of three replications on March 27, 1977, and April 13, 1977. Each sample was placed in a plastic container slightly larger than the plugs. Holes in the bottom of the containers provided adequate drainage. Samples were then transported to Blacksburg, Virginia, to undergo a controlled freeze test. The dormant plugs taken on March 27, 1977, were subjected to controlled freezing. Dormant plugs taken on April 13, 1977, were placed in a greenhouse (10-35C) for one month prior to freezing. A clipping height of 5 cm was maintained as samples were kept under a mist system.

All samples were watered to bring them above field capacity and allowed to drain for 24 hours before placing them in a dark room at 2.8C ± 1.6C for a minimum of 24 hours. Immediately after removing the plugs from the dark cold room a 24 gauge copper-constantan thermocouple was inserted into the soil at the center of each plug to a depth of 1.3 cm. Plugs were then put into cardboard boxes and covered with 5 cm of polyurethane insulation, and then placed into a Revco freezer set at -10C equipped with a fan to modify temperature extremes. In preliminary work it was found that with this arrangement, soil and surface temperatures varied less than 1C. The temperature of each plug was monitored with a Leeds and Northrup multi-point recorder. The cooling rate of the samples was 3C ± 1C per hour. Plugs were removed from the freezer when soil temperature reached -2, -4, and -6C, and were immediately returned to the dark cold room and allowed to thaw for 48 hours. After this post freeze treatment the samples were transferred to a greenhouse for regrowth. A clipping height of 5 cm was maintained and samples were kept moist with a mist system. Dormant test samples from March 27 were visually rated for turf cover (soil cover with green turf) and then calculated to a percent of the check (percent turf cover from regrowth when compared to unfrozen checks).

Actively growing test samples from April 13 were visually rated for percent survival (percent turf cover after freeze ÷ percent turf cover before freeze). A split plot experimental design was used. Data were subjected to analysis of variance.

RESULTS

Experiment 2. Cold Tolerance of Five Cultivars of *Cynodon* sp.

COLD HARDINESS TESTS

Dormant Samples:

After 2 weeks recovery from freezing at -2C (Table 4) 'Midiron' showed only a 10 percent decrease in cover compared to the unfrozen check whereas both 'Tifdwarf' and 'Tifgreen' lost almost 40 percent cover. Cultivars 'Tifway' and 'Tufcote' displayed the greatest amount of injury at the -2C and -4C treatments. 'Midiron', 'Tifdwarf', and 'Tifgreen' were each injured similarly at -4C. All cultivars were severely injured when exposed to -6C.

Results obtained after 3 weeks of recovery were similar to the 2 week ratings. It should be noted, however, that 'Tifgreen' had a large increase in turf coverage ratings at both the -2 and -4C treatments (Table 5).

The ground coverage of 'Tifgreen' after 4 weeks recovery was 28 percent, 40 percent and 15 percent higher at -2, -4, and -6C respectively than after 2 weeks of regrowth (Table 6). 'Midiron' and 'Tufcote' at the -2C treatment decreased in coverage at the 4 week rating. These decreases seemed to be caused by clipping the plugs before rating, thus affecting the coarser textured grasses more than the finer textured 'Tifdwarf', 'Tifgreen', and 'Tifway'.

Actively Growing Samples:

Although after 4 weeks of regrowth from dormancy and before freezing, 'Tifgreen' and 'Tifdwarf' showed significantly more coverage

Table 4. Live turf cover two weeks after exposing dormant bermudagrass to three freezing temperatures.

	Temperatures C			
Cultivars	-2	-4	-6	Avg.
	% unfrozen check			
Midiron	90	28	T[†]	39a
Tifdwarf	61	38	2	34a
Tifgreen	64	43	2	36a
Tifway	40	7	1	16b
Tufcote	27	5	1	11b
Avg.	56A	24B	1C	

Values with a letter in common do not differ significantly at the 5% level.

Avg. compared separately from other values.

[†]T=trace.

Table 5. Live turf cover three weeks after exposing dormant bermudagrasses to three freezing temperatures.

	Temperatures C			
Cultivars	-2	-4	-6	Avg.
	% unfrozen check			
Midiron	90	36	T[†]	42a
Tifdwarf	62	37	2	34a
Tifgreen	78	58	4	47a
Tifway	52	10	1	21b
Tufcote	38	5	1	15b
Avg.	64A	29B	2C	

Values with a letter in common do not differ significantly at the 5% level.

Avg. compared separately from other values.

[†]T=trace.

Table 6. Live turf cover four weeks after exposing dormant bermudagrasses to three freezing temperatures.

	Temperatures C		
Cultivars	-2	-4	-6
	% unfrozen check		
Midiron	81aAB	46bB	2cA
Tifdwarf	78aAB	51bB	6cA
Tifgreen	92aA	83aA	17bA
Tifway	64aB	18bC	2bA
Tufcote	38aC	11bC	0bA

Values with a letter in common do not differ significantly at the 5% level. Upper case letters compare values in columns; lower case letters compare values in rows.

than 'Midiron', 'Tifway', or 'Tufcote' (Table 7), the freezing treatments killed the leaves of all cultivars. There was no significant difference among the cultivars at any one freezing temperature 3 weeks (Table 8) or 5 weeks (Table 9) after freezing. Freezing treatments, however, caused highly significant decreases in recovery of all cultivars as temperatures were lowered.

After 3 weeks, 'Midiron' exhibited only 11 percent decrease in ground coverage from exposure to -2C (Table 8). This was 19 percent less injury than the next best cultivar ('Tifgreen') and 56 percent less injury than the poorest rated cultivar ('Tifway'). However, exposure to -4C caused 'Midiron' to have 10 percent less ground cover than 'Tifgreen' and 7 percent less than 'Tufcote'. All cultivars were severely injured at -6C.

Date taken five weeks after freezing showed the recuperative potential of 'Tifgreen' and 'Tifdwarf' at all temperature treatments when compared with the three week observations (Table 9).

Table 7. Percent of live turf cover after four weeks regrowth for five bermudagrass cultivars before exposing samples to freezing temperatures.

Cultivars	% Cover Before Freeze
Midiron	63b
Tifdwarf	89a
Tifgreen	90a
Tifway	73b
Tufcote	69b

Values with a letter in common do not differ significantly at the 5% level.

Table 8. Live turf cover as percent of regrowth for five actively growing bermudagrass cultivars after exposure to three freezing temperatures. Data taken three weeks after freeze.

	Temperatures C			
Cultivars	-2	-4	-6	Avg.
	% regrowth			
Midiron	89	24	3	39a
Tifdward	42	26	1	23a
Tifgreen	71	34	T[†]	35a
Tifway	34	9	0	14a
Tufcote	58	31	T	30a
Avg.	59A	25B	1C	

Values with a letter in common do not differ significantly at the 5% level.

Avg. compared separately from other values.

[†]T=trace.

Table 9. Live turf cover as percent of regrowth for five actively growing bermudagrass cultivars after exposure to three freezing temperatures. Data taken five weeks after freeze.

	Temperatures C			
Cultivars	-2	-4	-6	Avg.
	% regrowth			
Midiron	83	27	4	38a
Tifdwarf	58	38	2	33a
Tifgreen	81	37	2	40a
Tifway	36	13	0†	17a
Tufcote	54	28	T†	28a
Avg.	63A	29B	2C	

Values with a letter in common do not differ significantly at the 5% level.

Avg. compared separately from other values.

†T=trace.

MATERIALS AND METHODS

Experiment 3. Winter Hardiness and Wear Tolerance of Six Cultivars of *Cynodon* sp.

Plots of six cultivars of *Cynodon* spp. ('Midiron', 'Tifgreen', 'Tifdwarf', 'Tifway', 'Tufcote', and an experimental cultivar) were established by sprigging on June 29, 1976, in Blacksburg, Virginia, using a randomized block design with three replications. The soil, a typic Hapludult clayey, kaolinitic, mesic, (Lodi silt loam) had a high level of P (156 kg/ha), a medium level of K (176 kg/ha) and a pH of 6.3. These analyses were completed in the Virginia Polytechnic Institute and State University Extension Soil Testing Laboratory. Immediately after sprigging .5 kg/are of soluble N at 2 to 4 week intervals until early September. The plots were topdressed with soil immediately after sprigging and again on August 9, 1976. All cultivars were maintained at 1.3 cm clipping height. Irrigation was used to maintain plant growth.

Simulated traffic was applied to each plot on September 28, November 3, 1976, and February 17, 1977 (with ground frozen) with a golf spike studded roller suspended with roller bearing hangers from a double track and powered by an oscillating electric motor. The roller was 30 cm long and 5 cm in diameter with spikes placed in 8 alternating rows, 2 cm apart, and centered at 2.54 cm. Four hundred passes were made with an additional four hundred passes perpendicular to the first. Data were recorded by visual observations made on May 27, 1977. A split plot experimental design was used and data were subjected to analysis of variance.

RESULTS

Experiment 3. Winter Hardiness and Wear Tolerance of Six Cultivars of *Cynodon* sp.

The winter of 1976-77 was one of the most severe on record, resulting in record low air and soil temperatures in Blacksburg, Virginia (Table 1-Appendix).

'Midiron' sufferred significantly less injury from the winter than any of the six bermudagrass cultivars used in this experiment (Table 10). 'Midiron' was also the only cultivar that sufficiently survived the winter to obtain data to measure the resistance of wear. Wear treatments applied on September 28, 1976, and November 3, 1976, resulted in significantly more injury than when applied on February 17, 1977, while the ground was frozen (Table 11). The February treatment had a similar survival rate as did the 'Midiron' not receiving the wear treatments.

Table 10. Percent live turf cover ratings for six field grown bermudagrass cultivars taken on May 27, 1977.

Cultivars	% Cover
Midiron	48a
Experimental	17b
Tifdwarf	2b
Tifgreen	1b
Tifway	0b
Tufcote	0b

Values with a letter in common do not differ significantly at the 10% level.

Table 11. Percent live turf cover ratings for field grown 'Midiron' bermudagrass exposed to three dates of wear. Data taken on May 27, 1977.†

	Date of Wear			
Cultivar	Sept. 28	Nov. 3	Feb. 17	Check
Midiron	0b	17a	50a	48a

Values with a letter in common do not differ significantly at the 1% level.

†Of the six cultivars tested only 'Midiron' survived the wear treatments.

DISCUSSION

Experiment 1.

Deacclimation treatments prior to freezing and near freezing temperatures affected stolon buds differently than rhizome buds. Growth from stolon buds (Table 3) declined; however, rhizome bud growth (Table 2) was actually enhanced as deacclimation periods lengthened.

Regenerative parts of dormant bermudagrass stolons appeared to lose cold tolerance within a few days after warm deacclimation periods. These findings agree with those made by Edgerton (1954) on peach twigs. Such loss of cold tolerance may depend upon the combined effects of the temperature and the duration of exposure (Smith, 1964). Increasing the viability of bermudagrass rhizome buds from warm deacclimation treatments could have resulted from the physiological effects of warm temperatures in reversing degenerative changes caused by exposure to prolonged low temperatures. Warm temperatures have been reported to reverse injury from chilling temperatures in sweet potato roots (Lieberman et al., 1958), cotton seedlings (Stewart and Guinn, 1969), and corn seedlings (Creencia and Bramlage, 1971). In all cases, however, there was a threshold on the duration of low temperature exposure that the plant could endure, beyond which injury could not be reversed.

After warm deacclimation temperatures, temperatures below 0C were required to decrease growth of rhizome buds (Table 2). Both rhizome and stolon buds decreased in percent bud growth when exposed to -2C.

The combination of deacclimation with subsequent low temperatures reduced stolon bud viability greater than either factor acting alone (Table 3). This combination was not, however, synergistic in rhizome buds.

Rhizomes in all practicality will not be influenced by short durations of temperature increases or decreases in late winter because of the insulating effect of the soil surrounding the rhizome. Stolons, however, which grow on the soil surface, are susceptible to environmental fluctuations. Possibly stolon buds were less viable than rhizome buds because environmental factors cause deacclimation of stolon buds more than rhizome buds.

Prolonging the storage after exposure to low temperatures reduced the viability of both stolon and rhizome node buds. This suggests that continuation of the dormant condition on into spring could be an important contributing factor to the decrease in winter survival of both bermudagrass rhizome and stolon buds.

The most severe injury of stolon node buds resulted from the combined effect of temperature stress and storage duration after exposure to low temperatures (Table 3). Rhizome node bud injury, however, appeared related to the single independent influence of either low temperature or storage duration (Table 2).

Deacclimation treatments and storage durations were found to act independently in the injury of both stolon and rhizome node buds. A late winter warming period followed by a prolonged state of dormancy of either rhizomes or stolons will not in itself produce injury. Late winter warming periods followed by freezing or near freezing

temperatures, on the other hand, will interact with the length of dormancy causing increased injury of stolon node buds as deacclimation, temperature and dormancy stresses increase. This injury will, therefore, lessen with decreased deacclimation periods, shorter periods of dormancy, and less severe low temperature exposure.

Experiment 2.

Early recovery ratings suggest that 'Midiron' is injured less than other cultivars at moderately severe freezing temperatures. The recuperative potential of 'Tifgreen' bermudagrass appeared greater than that of any other cultivars tested when dormant. In the non-dormant freeze test, 'Tifdwarf' as well as 'Tifgreen' displayed high recuperative potential. The survival of 48 percent of 'Midiron' under field conditions (Table 10) when other cultivar survival was low is further evidence of the winter hardy characteristics of 'Midiron'.

The high rating of 'Midiron' and the recuperative potential of 'Tifgreen' bermudagrass agree with results obtained by Juska and Murray (1974). In that study, however, they ranked 'Tufcote' as more winter hardy than 'Tifgreen' but less than 'Midiron'. In this study, 'Tufcote' appeared less hardy than 'Tifgreen'.

Because bermudagrass cultivars vary in recuperative potential it seems only logical that cultivars such as 'Tifgreen' that have been reported to have a fast recuperative potential could withstand a greater amount of injury from winter than a cultivar not possessing such a quality. Therefore, when comparing bermudagrass cultivars for cold tolerance by determining the killing temperature (the arbitrary designation of a certain percentage of survival, above which the

cultivar is said to have survived and below which it is said to have failed the test) could vary depending upon recuperative potential of the cultivar.

All cultivars survived the -4C artificial freeze test, whether dormant or actively growing.

Experiment 3.

'Midiron' was the only cultivar that withstood the winter conditions in the field test with any degree of success. Possibly 'Midiron' is able to withstand other factors which affect winter survival in addition to low temperature. These factors might include prolonged periods of dormancy and mechanical injury from traffic. In this study recovery from imposed traffic was least in fall but increasing as winter progressed (Table 11). Survival of bermudagrass may therefore be further limited by mechanical injury from traffic prior to dormancy.

SUMMARY AND CONCLUSIONS

Winter survival is a main deterrant in using bermudagrasses (Cynodon sp.) for turf in the Northern region where semitropical grasses are adapted.

Effects of deacclimation, low temperature, dormancy periods, and imposed traffic were investigated to ascertain how they affect winter survival of bermudagrass. Three experiments were conducted in the field and laboratory. Data were collected 1) on percent growth from rhizome and stolon node buds after being subjected to deacclimation, followed by exposure to severe low temperatures and subsequent cold storage periods; 2) percent regrowth after freezing temperatures of five bermudagrass cultivars frozen in a dormant or a full deacclimated condition; and, 3) spring recovery from bermudagrass field plots subjected to traffic prior to and during dormancy.

Rhizomes and stolons subjected to -4 or -6C did not survive. Deacclimation of rhizomes up to 8 days augmented growth as compared to no deacclimation. Increased storage periods caused decreased rhizome growth. At +2 and 0C, the percent rhizome growth was similar and significantly higher than at -2C.

Without storage, stolon growth declined after 8 days deacclimation. After 45 or 90 days of prolonged dormancy, significant reductions in growth from stolon buds occurred after 4 days deacclimation.

All cultivars frozen, either while dormant or actively growing, survived at -4C. 'Tifgreen' bermudagrass frozen while dormant, and 'Tifgreen' and 'Tifdwarf' frozen while actively growing, had high

recuperative regrowth potentials.

Comparing cultivars under field conditions, 'Midiron' possessed the best winter survival. 'Midiron' was also the only cultivar that survived under simulated traffic. Traffic imposed immediately prior to dormancy of bermudagrass reduced spring recovery more than for traffic imposed during winter.

The conclusions that can be made from these studies are as follows:

1. Deacclimated stolons are more susceptible to low temperature injury than deacclimated rhizomes.
2. Lengthening dormancy will decrease viability of dormant stolons and rhizomes buds.
3. Cold tolerance of bermudagrass cultivars is better ascertained in a dormant than a non-dormant state.
4. Traffic imposed prior to dormancy is more detrimental to winter survival of bermudagrass than when imposed while dormant.
5. Of the bermudagrasses studied, 'Midiron' was most resistant to winter injury.

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APPENDIX

Table 1. Maximum and minimum soil and air temperatures (Fahrenheit) recorded at a depth of 7.6 cm and a height of 1.37 m at Blacksburg, Va. from Jan. 1 to March 30 during the period 1975-1977.

Date	1975				1976				1977			
	Air		Soil		Air		Soil		Air		Soil	
Jan.	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	60.0	28.5	44.0	39.0	44.0	24.0	40.0	37.0	16.0	3.0	28.0	25.5
2	42.0	20.0	39.0	35.0	47.0	21.0	40.5	35.0	25.0	8.0	28.0	25.0
3	41.0	38.5	38.0	34.0	46.0	27.0	40.0	37.0	29.0	16.0	28.0	27.0
4	41.0	29.5	39.0	35.5	27.0	10.0	37.0	32.5	39.0	25.0	30.0	28.0
5	45.0	23.5	38.5	33.0	22.0	4.0	32.5	31.0	34.0	29.0	30.0	29.0
6	32.0	24.0	35.0	32.5	41.0	7.0	31.5	30.5	33.0	28.0	30.0	29.0
7	52.0	27.0	39.0	33.5	44.0	24.0	32.0	31.0	30.0	12.0	29.0	29.0
8	47.0	29.5	37.0	34.0	42.0	9.0	32.0	31.0	33.0	8.0	29.0	28.0
9	62.5	34.5	42.0	36.5	19.0	4.0	31.0	30.0	29.0	18.5	29.0	28.5
10	57.5	31.0	40.0	35.5	36.5	6.0	30.0	29.5	30.0	7.0	29.0	27.5
11	63.0	39.5	45.5	40.0	36.0	19.5	30.0	30.0	15.0	2.0	28.5	27.5
12	41.5	30.0	40.5	38.0	45.0	25.0	31.0	30.0	21.5	0.5	28.5	28.0
13	34.0	16.0	38.0	33.0	48.0	18.0	31.0	30.0	24.5	-5.0	28.5	28.0
14	22.0	12.0	33.0	30.0	46.0	24.5	31.0	30.0	36.0	21.0	29.0	28.5
15	41.0	10.5	32.0	30.0	39.0	21.0	31.0	30.0	36.0	22.5	29.0	29.0
16	36.0	25.0	30.0	30.0	38.0	25.0	31.0	30.5	26.0	-9.5	29.0	27.0
17	36.5	19.0	30.0	29.5	30.5	9.0	31.0	30.5	8.0	-13.0	27.0	24.5
18	45.0	26.0	32.5	30.0	14.0	2.0	30.5	30.0	17.0	2.5	25.5	23.5
19	48.0	34.0	35.5	30.0	34.0	-1.0	30.0	29.0	18.0	1.5	25.0	23.0
20	45.5	14.0	35.5	33.0	34.0	22.0	30.0	29.5	26.0	13,0	26.0	24.0
21	34.5	8.0	33.0	33.0	33.0	18.0	30.0	29.5	21.5	16.0	26.0	24.0
22	42.0	24.5	34.0	33.0	26.0	15.0	30.0	29.5	20.0	11.0	25.0	23.0
23	47.0	23.0	34.5	32.0	50.0	11.0	30.5	29.0	29.0	5.5	26.0	21.5
24	57.0	22.0	39.5	31.5	57.0	36.0	31.0	30.5	29.0	23.0	27.0	25.0
25	51.0	32.0	42.0	38.0	43.0	31.5	31.0	30.0	32.0	21.5	28.5	27.0
26	37.0	30.0	38.0	35.0	55.5	40.0	36.0	31.0	34.0	19.0	28.0	26.0
27	55.0	30.0	40.0	32.5	55.0	27.0	36.5	33.0	37.0	24.0	29.0	27.0

Table 1. (continued)

Date	1975				1976				1977			
	Air		Soil		Air		Soil		Air		Soil	
Jan.	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
28	71.0	32.5	44.0	34.5	29.5	18.0	33.0	31.5	38.5	0.0	29.0	23.0
29	68.0	44.0	45.0	40.0	37.0	27.0	32.5	31.5	15.0	-2.0	24.5	18.5
30	52.0	34.5	44.0	40.0	37.0	23.0	32.0	31.0	23.5	6.0	25.0	17.0
31	51.0	39.0	43.0	41.0	47.5	29.0	39.0	31.5	23.0	6.0	24.0	16.5
Tot.	1456.0	817.5	1181.0	1062.5	1199.5	576.5	1014.5	962.0	828.5	320.0	858.0	788.0
Avg.	47.0	26.4	38.1	34.3	38.7	18.6	32.7	31.0	26.7	10.3	27.7	25.4
Feb.												
1	41.5	33.0	41.5	39.5	43.0	29.0	37.0	35.0	26.0	10.0	25.0	17.0
2	38.0	32.0	40.0	37.0	29.0	2.0	35.5	31.0	39.0	16.0	27.0	18.0
3	34.5	27.0	38.5	35.5	38.0	15.0	31.0	30.5	43.5	22.5	28.0	22.0
4	29.0	23.5	35.0	34.0	58.0	20.0	36.0	30.5	44.5	31.0	28.5	26.0
5	40.0	28.0	35.5	34.0	46.0	28.0	37.5	32.0	38.0	8.0	28.5	24.0
6	45.5	31.0	35.0	34.0	49.0	17.5	39.0	34.0	18.5	1.5	25.5	20.0
7	31.0	18.0	34.0	33.0	24.0	10.0	34.0	31.5	23.5	2.0	25.0	18.0
8	46.0	14.0	33.5	32.0	31.5	16.0	31.5	31.0	34.0	2.0	27.0	18.0
9	35.5	14.0	32.0	32.0	42.5	24.0	32.5	30.5	45.0	8.0	28.0	20.0
10	36.0	16.0	32.0	30.0	68.0	26.0	39.0	31.0	54.0	23.0	28.5	24.5
11	46.5	25.5	33.5	30.5	57.0	35.0	41.5	36.5	56.0	22.0	29.0	26.0
12	48.0	32.5	35.0	32.0	54.5	23.5	41.5	34.0	41.0	25.5	29.0	28.0
13	38.0	25.5	34.0	31.0	62.0	33.0	43.0	37.0	40.0	29.5	30.0	28.5
14	45.0	21.0	34.0	30.0	54.0	34.0	46.0	41.0	49.0	27.5	29.5	28.0
15	55.0	31.0	39.5	31.5	61.0	34.0	46.0	40.0	35.5	19.5	29.5	28.5
16	49.0	32.0	39.0	34.0	72.0	45.0	49.0	42.0	22.0	13.5	29.0	25.5
17	51.0	46.5	41.0	39.0	64.0	54.0	50.0	46.0	27.5	9.0	27.5	23.0
18	56.0	38.0	42.5	39.0	58.0	46.0	47.5	45.0	28.5	10.0	27.0	24.0
19	50.5	31.0	42.5	39.0	59.5	41.0	50.0	43.5	48.5	14.0	29.0	25.0
20	47.5	21.0	42.0	35.5	57.5	32.0	49.5	42.0	34.0	20.0	29.0	28.0

Table 1. (continued)

Date	1975				1976				1977			
	Air		Soil		Air		Soil		Air		Soil	
Feb.	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
21	54.0	28.0	42.5	34.0	55.5	31.0	46.5	42.5	27.0	17.5	28.5	27.0
22	59.0	26.0	43.5	35.0	54.0	30.0	46.0	42.0	60.5	14.0	29.5	25.0
23	70.0	48.0	47.0	42.0	35.0	22.0	43.0	39.0	62.5	28.5	30.0	29.0
24	66.0	38.0	50.0	45.5	62.0	20.0	45.5	36.0	57.0	44.0	31.5	30.0
25	51.0	33.0	45.0	41.0	67.0	24.0	47.5	38.0	62.0	37.5	NR	NR
26	53.5	33.0	43.5	39.0	64.0	35.5	47.0	41.5	74.0	31.0	NR	NR
27	46.5	28.0	42.5	38.0	65.5	36.0	50.0	42.0	58.0	32.0	NR	NR
28	55.0	21.5	42.5	35.0	69.5	29.0	49.0	41.0	39.0	28.5	32.0	29.0
29					72.0	31.0	51.0	42.0				
Tot.	1318.5	786.0	1096.5	992.0	1573.0	823.5	1242.5	1087.5	1188.0	547.5	711.0	612.0
Avg.	47.1	28.1	39.2	35.4	54.2	28.4	42.8	37.5	42.4	19.6	28.4	24.5
Mar.												
1	43.0	26.0	40.0	36.5	72.0	38.0	52.0	44.5	40.0	23.0	30.0	29.0
2	26.0	16.0	38.0	35.0	75.0	37.0	54.0	45.0	46.0	22.0	30.0	29.0
3	26.5	18.0	35.0	32.0	78.5	43.0	55.0	47.0	56.0	25.0	33.5	29.0
4	38.0	21.0	37.0	31.5	81.5	43.5	57.0	48.0	68.0	47.0	41.0	33.0
5	51.0	14.0	40.5	31.5	77.0	57.0	56.0	51.0	59.0	41.0	41.0	31.0
6	60.5	22.0	43.0	33.0	57.0	35.0	53.0	47.0	48.0	39.5	38.5	34.5
7	53.0	36.0	42.0	38.0	50.5	29.0	50.0	44.0	46.0	30.5	40.0	33.5
8	39.5	23.0	41.0	35.0	44.0	33.0	45.5	43.0	58.0	26.0	41.5	31.0
9	39.0	14.0	39.0	32.0	33.5	30.0	44.0	41.0	67.5	25.0	45.0	32.0
10	35.0	27.5	35.0	35.0	53.0	30.0	47.0	40.5	62.0	33.0	45.0	35.0
11	48.0	34.0	37.0	35.0	56.5	34.0	49.5	41.5	62.0	45.0	45.0	40.5
12	48.0	35.5	40.0	35.0	49.0	35.5	45.0	43.0	61.0	53.5	47.0	43.0
13	55.0	45.5	44.5	40.0	60.5	28.0	50.0	44.0	66.0	48.0	54.5	46.0
14	45.0	32.0	44.5	38.0	54.0	25.0	48.0	41.0	64.0	45.0	52.5	45.0
15	47.0	29.5	43.0	35.0	56.5	23.0	47.5	41.0	76.5	33.0	55.5	41.0
16	45.5	36.0	41.0	38.5	52.5	23.0	45.0	41.5	62.0	44.0	53.0	45.0

Table 1. (continued)

Date	1975				1976				1977			
	Air		Soil		Air		Soil		Air		Soil	
Mar.	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
17	46.5	35.0	42.5	38.0	30.0	18.0	43.5	39.5	57.5	39.0	50.5	41.5
18	44.5	36.0	42.0	39.0	58.5	19.0	46.5	37.0	69.0	44.5	52.0	45.0
19	52.0	40.0	44.0	40.0	64.0	37.5	49.0	42.0	51.0	36.5	50.0	42.0
20	60.0	42.5	46.5	40.5	72.5	33.5	52.5	43.0	60.0	37.0	51.0	43.0
21	74.5	30.5	51.0	40.0	63.0	44.0	52.5	48.0	46.5	28.0	45.0	40.0
22	60.0	49.5	47.5	45.0	50.5	28.0	50.0	44.5	45.5	28.0	44.0	38.5
23	75.0	44.0	53.5	43.0	60.0	19.0	51.0	41.0	44.0	24.0	43.0	35.0
24	67.0	52.0	53.0	49.0	66.0	27.0	52.0	42.0	46.0	26.0	44.5	36.0
25	58.0	33.5	52.0	45.5	59.0	40.5	52.5	46.5	54.0	28.0	47.5	37.0
26	44.0	26.0	46.0	40.0	69.0	32.0	55.5	46.0	64.0	32.0	50.5	38.0
27	43.0	22.0	42.0	39.0	66.0	43.0	54.5	50.5	64.0	31.0	51.0	40.0
28	43.5	32.0	42.0	39.5	66.5	33.0	56.5	46.5	64.0	51.5	53.0	46.0
29	62.0	37.5	47.5	41.0	59.0	36.0	50.5	47.5	72.5	51.5	58.0	48.5
30	57.5	32.5	47.5	41.0	58.0	49.0	53.0	49.0	70.0	54.0	58.5	52.0
31	54.0	29.0	48.0	36.0	55.0	40.0	51.0	50.0	60.0	44.0	57.0	49.5
Tot.	1542.0	972.0	1346.0	1177.5	1848.0	1043.5	1568.5	1376.0	1810.0	1135.5	1448.5	1209.5
Avg.	49.7	31.4	43.4	38.0	59.6	33.7	50.6	44.4	58.4	36.6	46.7	39.0

VITA

David R. Chalmers was born in Detroit, Michigan, on March 10, 1951, to James S. and Joyce E. Chalmers. He attended high school at Southfield Senior High School, graduating in June, 1969. He enrolled at Wayne State University in September, 1969, and then transferred to Michigan State University in September, 1972, where he received a B.S. degree in Crop Science in December, 1974. In the fall of 1975, he enrolled in graduate school at the Virginia Polytechnic Institute and State University to pursue a Master of Science degree in Agronomy which was received in June of 1978. From September of 1977 to May of 1978 he served as an Instructor at Ferris State College in Big Rapids, Michigan.