

AN ABSTRACT OF THE THESIS OF

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Title: WATER USE OF COOL SEASON AND THEIR EFFECT ON
GRAPEVINE (Vitis vinifera) GROWTH AND
DEVELOPMENT

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The use of grass cover crops is a recommended practice in nonirrigated vineyards in the Willamette Valley, Oregon. Two studies were initiated to investigate the competitive and noncompetitive effects of grass cover crops on the growth and development of Pinot noir grapevines. Two greenhouse pot culture experiments were performed to investigate the allelopathic potential of cool season grasses. In the first experiment grass and uncultured grapevine cuttings were established simultaneously in 4 liter pots filled with sand with no fallow strip. Water and nutrients were supplied at luxury levels so as to be nonlimiting. Differences in rooting and growth of the grapevines was a function of the growth habit of the grass. Allelopathy was not apparent. In the second greenhouse experiment perennial ryegrass (Lolium perenne cv. 'Elka') was established in 15 liter sand:peat filled pots before uncultured grapevines were planted directly in the grass. Water and nutrients were supplied at luxury levels. Root initiation was inhibited under the ryegrass, with only 24% of the

cuttings initiating rooting. Allelopathy may have been involved. A 2 year field study was also initiated to investigate the consumptive water use of 4 cool season grasses (L. perenne, A. tenuis, F. arundinacea, and D. glomerata) used as cover crops in Oregon vineyards under low maintenance conditions. Seasonal evapotranspiration and total depletion of soil water did not differ significantly among species, and was significantly greater than bareground in the early summer months. In late summer months evapotranspiration of the grasses was not significantly different than evaporation from bareground. Establishment of unrooted grapevine cuttings placed directly into established perennial ryegrass turf is unlikely to be successful. Once vineyards are well established, grass cover crops can provide benefits to the vineyard without strong competition for soil water during the summer months.

WATER USE OF COOL SEASON GRASSES AND THEIR EFFECT ON
GRAPEVINE (Vitis vinifera) GROWTH AND DEVELOPMENT

by

Jean A. Doty

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WATER USE OF COOL SEASON GRASSES AND THEIR EFFECT ON
GRAPEVINE (Vitis vinifera) GROWTH AND DEVELOPMENT

Chapter 1

INTRODUCTION

Cover cropping is a recommended management practice in vineyards in the Willamette Valley, Oregon. Grass cover crops can help prevent soil erosion, improve trafficability, provide a cool humid atmosphere in the summer months, and control excess vigor (Vomocil, 1985; Butler, 1986). Disadvantages of grass cover cropping include increased frost hazard, increased rodent pests, and competition for nitrogen and water (Vomocil, 1985; Butler, 1986) and chemical inhibition (Putnam, 1986).

Interference describes plant-plant or plant-environment interactions. These interactions can be positive, negative, or neutral. Competition and allelopathy are types of negative interference (Burkholder, 1952).

Competition is the mutually adverse effects of organisms (plants) which utilize a resource that is in short supply (Barbour, et al., 1980). Competition studies between woody perennials and turfgrasses demonstrate competition occurs for mineral nutrients (Nielson and Wakefield, 1981), water, and light (Mouat and Walker, 1959; Messenger, 1980; Morlat, 1981; Neely, 1984) resulting in reduced growth of both aboveground and belowground plant parts. Allelopathy is the alteration in the growth and behavior of associated plants which is not a function of competition. Allelopathy can be expressed as either an inhibition or

stimulation of plant growth (Molisch, 1937; Rice, 1983) and occurs through the release of substances into the immediate environment. These substances may directly affect neighboring plants, or indirectly affect them through alterations in the environment (Rice, 1983).

Two studies were performed to investigate competitive ability of various grass species for water under low maintenance conditions and potential noncompetitive effects of grass cover crops on grapevine growth and development. Two greenhouse pot culture experiments were designed to investigate the allelopathic potential of various grass species grown with grapevines in 4 liter sand-filled pots (1987) and 15 liter sand and peat- filled pots (1988). A two year field experiment was initiated to measure water use of 4 grass species under low maintenance conditions in the Willamette Valley, Oregon.

The purpose of this research was to provide information on the relative competitiveness of the various cool season grass species for water, and to determine if any were potentially allelopathic.

Chapter 2

REVIEW OF LITERATURE

I. GRASS-WATER RELATIONS

A. Grass Cover Crops

Cover cropping in horticultural crops is a recommended practice to improve winter trafficability, increase water infiltration, improve soil structure, moderate soil temperatures, and reduce soil contamination (Vomocil, 1985; Butler, 1986). In the Pacific Northwest cover crops are recommended to reduce soil erosion (Vomocil, 1985). Other benefits specific to Pacific Northwest vineyards include quick extraction of late season moisture which can enhance early dormancy (Vomocil, 1985; Winkler, 1983).

Cool season grass species are used as cover crops in many horticultural crops. These species are grasses with an optimum temperature range for growth of 15-20 °C (Beard, 1983). The large number of native species and the variety of growth habits make these grasses attractive alternatives to conventional cover crops such as cereal grasses or legumes. Possible disadvantages of grass cover crops are competition, mainly nitrogen and soil water, cooler winter temperatures in the orchard and vineyard, increased frost hazard, and increased rodent pest problems (Vomocil, 1985; Butler, 1986; Shribbs, et al., 1986).

Cool season grass species commonly used as cover crops in the Pacific Northwest include Agrostis tenuis, Festuca arundinacea, Lolium perenne, and Festuca rubra (Cook, 1985). Less commonly used grass species include Dactylis glomerata, and Festuca ovina

(Amedullah, 1982; Ogg, 1983; Cook, 1985).

Colonial Bentgrass (Agrostis tenuis) is a bunchgrass but has the ability to produce both rhizomes and stolons (Vengris and Torello, 1982; Beard, 1983; Williams, 1985). It will go dormant in hot dry conditions (Vengris and Torello, 1982; Beard, 1983; Williams, 1985). Perennial ryegrass (Lolium perenne) is the dominant turfgrass species in the Pacific Northwest (Cook, 1985). It is quick to establish but may become clumpy. Perennial ryegrass is not as drought tolerant as other cool-season species (Ogg, 1983; Cook, 1985). Orchardgrass (Dactylis glomerata) is a bunch-type grass which lacks rhizomes and stolons. It forms a weak 'open' sod of low shoot density (Cook, 1985), greens up quickly in the spring, and demonstrates good heat tolerance (Peterson, 1985). Good performance requires 460 mm or more of annual irrigation or rainfall (Peterson, 1985). Tall fescue (Festuca arundinacea) is a coarse bunchgrass that is the most heat tolerant of the cool season grass species. Tall fescue may be replaced by more hardy invading grass species when stressed (Beard, 1983, Williams, 1985; Cook, 1985). Creeping red fescue (Festuca rubra) is easy to establish, and is hardy under 'normal' winter conditions (Amedullah, 1982). It has a slow vertical growth rate and exhibits a fair establishment rate (Beard, 1983). Red fescue is shade tolerant, but may require several mowings per year (Amedullah, 1982). Sheep fescue (Festuca ovina) is a low quality turfgrass because of its clumpy growth habit, but has shown promise for use for cover cropping. It is extremely drought resistant with moderate wear tolerance (Beard, 1983; Williams, 1985).

B. Seasonal Growth and Development

The optimum conditions for grass germination is at air temperatures between 15.6-23.9 °C, and soil temperatures over 10 °C (Beard, 1983; Cook, 1985). Grass root systems develop rapidly (Troughton, 1957). Lolium perenne and Agrostis tenius are quick to germinate and become established, F. arundinacea and F. ovina are much slower. Under natural conditions, grass growth is controlled by the environment. Root and shoot growth proceed until conditions become too severe for maintenance of healthy grass plants (Brown, 1939; Beard, 1983; Cook, 1985). The grass, depending on the species, may become dormant. Root growth takes place during the end of the shoot growth stage, and before shoot growth begins in the spring (McCarty and Price, 1942). Shoot growth subsides during flowering (Baker, 1955) resulting in a reduction of roots (Troughton, 1957). Optimal temperatures for rooting and growth of cool season species has been estimated to be between 10-15.6 °C (Brown, 1939). Root growth occurs at soil temperatures from freezing (0 °C) (Collison, 1935) to near 26.7 °C before growth cessation (Brown, 1939). Decreases in root growth during hot summer months may be a result of high temperatures in the upper soil layers (Ueno and Yoshihara, 1967). When temperatures become too high, growth slows or stops. The grass becomes dry and brown and will remain dormant, under nonirrigated conditions, until early fall rains (Baker, 1967; Cook, 1985). In the fall, soil and air temperatures begin to decrease and a flush of root growth occurs (Stuckey, 1941). Root growth may continue as

long as the temperature of the soil remains above freezing. Another flush of root growth occurs in the spring with subsequent greening of the shoots. Growth continues until flowering (Cook, 1985).

C. Rooting Under Natural Conditions

The majority of grass rooting research is on high maintenance turfgrass. Grass cover crops are grown under low maintenance conditions. Studies on rooting under natural conditions may apply to grass grown under low maintenance.

During seedling growth, roots rapidly penetrate the soil (Troughton, 1956). Differences between depth and lateral spread of various species is visible, but not as visible as differences in total length (Plummer, 1943; Troughton, 1956). Early establishing species have deeper roots the first year of growth, while late season species have smaller roots the first year (Kauter, 1933).

Distribution of grass roots in the soil is influenced by many factors. The fibrous grass roots are concentrated in the upper soil layers (Rappaport, 1938; Troughton, 1957; Beard, 1983; Cook, 1985). The greatest root weight is found in the upper 0.50 m, while the greatest total length occurs at a lower depth (Rappaport, 1938). Total root growth of 7,775 mm of roots in the top 0.55 m of soil, with 2335 mm in the top 0.05 m has been reported under swards in noncompetitive environments (Rappaport, 1938).

Rooting depth in unmown swards is estimated to be to 1.22 m (Garwood and Williams, 1966). Sowing time also affects rooting,

with root growth being restricted to the upper 0.6 m in autumn sown swards. Spring sown swards root to 0.92 m, with white root growth present to 0.46 m. Both sowing times result in roots concentrated in upper soil layers, but autumn roots live longer and root deeper (0.81-1.93 m) (Jaques, 1941). Data on rooting depths under natural conditions show F. ovina and Lolium spp. to root to 0.61 m, and D. glomerata to root to 1.0 m. (Troughton, 1957). Rooting studies with L. perenne, P. pratensis, and F. arundinacea show 75% of P. pratensis roots to be in the top 12 cm of soil, while both L. perenne and F. arundinacea have only 50% of their roots in the top 0.12 m (Sheffer, et al., 1987). Relative root distribution of cool season grass species shows sheep fescue to have 98.9% of its roots in the top 1.22 m of soil, with 98.93% of those being between 0-0.61 m; Kentucky bluegrass has 97.4% of its roots from 0-1.22 m, with 97% of those being found between 0-0.61 m. Approximately 95% of the roots of chewings fescue are in a range of 0-1.22 meters (Partridge, 1941). Weight of the roots in the 0-0.61 m range is 85.2 g (Sheep fescue), 66.7 g (Kentucky bluegrass), and 64.7 g (Chewings fescue) (Partridge, 1941).

D. Water Use Under Natural Conditions

Contemporary work on water use of swards under natural conditions is limited. Perennial ryegrass swards, grown on a light alluvial soil with available water equal to 27.9 mm per 0.30 m soil, use approximately 510 mm of water from April to June in nonirrigated conditions, and deplete soil water down to 0.92 m below the surface in continued water stress conditions (Garwood

and Williams, 1966). Water use in excess of 50.8 mm depresses grass growth, which in turn decreases water use (Garwood, 1967). Water is first depleted from upper horizons (0-0.30 m), being drawn from progressively lower depths as drought conditions continue (Garwood and Williams, 1966). Capillary movement of water from the lower depths occurs at negligible rates, but root extensions occur which draw enough water to sustain plants in dry conditions (Troughton, 1957), however root extensions below a soil depth of 0.20 m have been shown to be insufficient at supplying water to grass plants (Wind, 1955).

Simulations of grass growth under natural conditions in greenhouses have shown that from May to September, Orchardgrass uses 78.7 mm of water, Chewings fescue uses 106.68 mm of water, Sheep fescue uses 114.5 mm of water, and Kentucky bluegrass uses 142.24 mm of water (Partridge, 1941).

E. Management Practices and Water Use

Effects of cultural practices on the growth and development of the grasses is important. Under moderate management practices (irrigation, 6-8 mowings/year, and seasonal fertilization) cool season turfgrasses evapotranspire from 2.4-7.5 mm day⁻¹ of water (Beard, 1983). Other estimates on evapotranspiration rates are from 3.88 mm day⁻¹ to 6.43 mm day⁻¹ (Shearman, 1986). Evapotranspiration (ET) accounts for evaporation from the soil surface and transpiration by the plant (Salisbury and Ross, 1978). This amount varies depending on the intensity of management.

Mowing causes a transfer of resources from the roots to the

shoots (Beard, 1983). Water use decreases with frequent mowing, and results in significantly lower root weights compared with unmown swards (Sadamori, et al., 1955; Baker and Garwood, 1966). Unmown grasses also exhibit greater stubble weight (Baker and Garwood, 1966). All grass species mown to 13 mm has lower total rooting when compared to 25 mm and 51 mm mowing heights (Falk, 1980). Higher grass mowing heights result in deeper roots (Falk, 1980)

Water use of C-3 grasses is greater than C-4 grasses under similar mowing treatments by about 20-45% (Biran, et al., 1982; Beard, 1983). Increasing mowing height increases water consumption from 3-15% (Biran, et al., 1981; Feldhake, et al., 1983). Grass mown to 50 mm increases water consumption by 15% compared to grass mown to 20 mm. Frequent mowings may result in decreased water use (Sadamori, et al., 1955).

Applications of nitrogen in unfertilized plots results in root and shoot growth, with lower percentages of roots (Falk, 1980). Small amounts of nitrogen also result in grasses with large deep root systems (Sills and Carrow, 1983). Winter root growth is highest with October-February applied nitrogen (Powell, et al., 1967) and is decreased by both no fertilization and by high rates of fertilizer. Relative nutrient absorption by roots is correlated to the diameter of the root, with roots greater than 0.9 mm removing nutrients from lower soil layers, and roots less than 0.7 mm restricted to nutrient uptake in the upper layers (Torbet, et al., 1981). Fertilization increases water use by 13% during summer months (Feldhake, et al., 1983), and increases overall

water use efficiency (Krogman, 1967).

Compaction does not affect the weight or distribution of grass roots, but does reduce soil porosity and water use (Sills and Carrow, 1983; O'Neil and Carrow, 1983). Long term studies show compaction to restrict root distribution (Sills and Carrow, 1983). Moderate compaction reduces water use by 21% while heavy compaction reduces water use by 45% (O'Neil and Carrow, 1983). Compaction increases bulk density, water retention, and soil strength while reducing aeration (Sills and Carrow, 1983; Donahue et. al, 1983).

F. Stress Tolerance

Stress tolerance of grass species determines responses of grasses to extremes in temperature, water stress, and traffic. Vineyards in the Pacific Northwest are non-irrigated and can be subjected to heavy traffic from farm equipment. It is important for grasses to withstand these extremes. Several mechanisms are utilized by grass plants to survive heat and water stress; (a) escape, (b) dormancy, (c) increase water absorption capabilities, (d) xeromorphic features, and (e) physiological capability to avoid dehydration (Beard, 1983).

Drought tolerance of grasses is attributed to rapid development of seminal roots. Under drought conditions, germination, tillering, rhizome, and stolon development is greatly reduced (Juska and Hansen, 1966). Under dryland conditions drought exposure kills Kentucky bluegrass, chewings fescue, creeping red fescue, and orchardgrass, while meadow fescue survives (Schultz

and Hayes, 1938). Grasses become dormant when water stressed (Weaver and Albertson, 1943; Gaskin, 1966; Beard, 1983), but exhibit vigorous growth with early spring or late autumn rains (Weaver and Albertson, 1943). Dormancy response results in dead above ground shoots which are easily regenerated upon adequate watering (Wallner, 1961).

Root growth is highly correlated to depth of soil moisture (Weaver and Albertson, 1943). Deep-rooted plants obtain moisture from a considerable depth in the soil and may be protected from drought injury. The genetic drought tolerance continuum in cool season grasses, is (from low to high) annual bluegrass, creeping bentgrass, colonial bentgrass, Kentucky bluegrass, perennial ryegrass, and tall fescue. Grasses can also be hardened to increase their ability to survive drought conditions. Hardening restricts water availability to plants to place them under constant but low water stress (Carroll, 1943).

Hard fescue, big bluegrass, and orchardgrass show inhibited germination in growth chambers at temperatures above 37.8 °C or below 21.1 °C (Rosenquist and Gates, 1961). Maximum shoot growth occurs at 29.4 C. Root growth continues until temperatures reach 46.1 C. Orchardgrass germinates best at 21.1 °C, while hard fescue and bluegrass germinate best at 29.4-37.8 °C. Cool season grasses are killed by temperatures of 48 °C (Julander 1945).

Nitrogen fertility does affect heat tolerance of grasses. Moderate doses does not reduce heat tolerance, but large single nitrogen applications may (Wehner, et al., 1985).

Wear tolerance continuum for cool season grasses (from high to

low) is L. perenne, P. pratensis, A. tenuis, and P. annua (Klecka, 1938). F. arundinacea is also highly tolerant to wear, while F. rubra exhibits moderate wear tolerance (Youngner, 1961). The presence of P. annua or broad-leaf weeds reduces the tolerance of all species (Youngner, 1961). P. annua alone can be very wear tolerant (Weinhaus, 1984). L. perenne and F. arundinacea demonstrate high wear tolerance, but recover slowly from wear damage (Shearman and Beard, 1975). Chewings fescue has low wear tolerance. Increasing mowing height increases wear tolerance of all species. Excessively wet or dry soils decreases wear tolerance (Shearman and Beard, 1975).

Interactions occur between cutting height, fertilization, and irrigation, and may affect grass drought and wear tolerance (Juska and Hansen, 1966; Julander, 1945). High nitrogen rates increase shoot growth at the expense of root growth. Drought tolerance decreases because of production of shorter roots. Succulent top growth resulting from nitrogen fertilization reduces grass wear tolerance. Spring-applied nitrogen plots survive drought better than fall-applied nitrogen plots because warmer soil temperatures increase root growth. Dormancy of the roots in the fall can result in the failure of grass plants to take up the nitrogen. Grasses are more sensitive to high temperatures when clipped and watered (Julander, 1945). Hardened plants, which are plants subjected to slight drought conditions, show increased resistance to heat and drought. Moderate grazing or mowing before water becomes limiting increases drought tolerance (Juska and Hansen, 1966; Beard, 1983).

II. GRAPEVINE-WATER RELATIONS

A. Seasonal Growth and Development

Seasonal growth and development of the grapevine begins when daily temperatures reach an average of 4-10 °C (Winkler, et al., 1974). Fluctuating temperatures in early spring may delay growth. When mean daily temperatures exceed the threshold, a rapid period of root growth occurs (Winkler, et al., 1974). Flowering and berry development occur in the late spring and early summer. The flower (berry) becomes a strong sink for photosynthate. Development continues through the summer months with berry development occurring in three stages. Stage one is the rapid enlargement phase and occurs after flower buds open. Stage two is the lag phase where very little growth or enlargement occurs. In stage three the berries enlarge rapidly and accumulate sugars. Shoot growth slows and at harvest, roots experience a second flush of growth (Winkler, et al., 1974). This is attributed to shunting of photosynthate to the roots for storage, which is essential for survival and initiation of growth in the spring (Winkler, et al., 1974). Fruit maturity and harvest take place in the fall, with leaf senescence occurring after the first frost. The vines then go dormant (Winkler, et al., 1974). The cycle continues the following spring when temperatures average 10 °C.

Root growth of grapevines occurs in the spring at 10-21 days after budbreak (Barnard, 1932; Nimi and Tonkata, 1970; Lilov and Andronova, 1976). Growth is slow, but increases over time reaching a maximum by midsummer (Freeman and Smart, 1976). Initiation of root growth is estimated to be favorable at soil tempera-

tures of 30 °C. Root growth declines from a maximum to a lower peak by mid-autumn (Winkler, et al., 1974).

Growth of root systems of woody perennials occurs through extension and branching (Richards, 1983). Extension roots range between 1-2 mm in thickness and grow rapidly. Estimations of the rate of growth are from 0.10 m day^{-1} (Hilton and Khatamian, 1973). These roots grow rapidly into unexplored soil (Richards and Cockroft, 1974). Branch roots arise from the interior of main roots at irregular intervals (Winkler, et al., 1974). Main roots grow rapidly and continue to increase in length and diameter while branch roots are being formed. Branch roots persist from season to season (Winkler, et al., 1974). Lateral roots arise from regions behind extension roots and develop at regular intervals (Richards and Cockroft, 1974).

Death and regeneration of roots occurs constantly, with finer roots dying weeks after arising (Reynolds, 1975). Roots are constantly replaced by newly emerging fine lateral roots under favorable soil conditions (Reynolds, 1975). Cycles of sluffing and subsequent regeneration of roots is believed to be the principal source of soil organic matter in perennial cropping systems (Rogers, 1968).

Root distribution studies in various soil types and textures reveal that the majority of roots occur in the top one meter of soil (Sequin, 1972). The 0.1-0.6 m zone contains many fine lateral roots with absorptive surfaces (Barnard, 1932; Randall and Coombe, 1978; Van Huyssteen and Weber, 1980a).

Barriers in the soil, such as compaction layers, high water

table, or a saline or acid zone, can restrict rooting depth.

Grapevines have been observed to penetrate compacted layers at 0.45 m, and gravel at 0.6 m (Safran, et al., 1975). In deep rich soil, roots are present to 2 m (Wakebayshi, et al., 1974).

Horizontal growth of grapevine roots averaged 3 m, and can extend to 7.5 m (Barnard, 1932).

B. Management Factors

Grapevine rooting depth and lateral spread are influenced by soil and cultural management practices. Grapevine planting density can affect the size, density, and distribution of the roots in the soil. In general as the planting density increases, the weight of the roots system decreases (Hildago, 1968). Reductions in spacing between vines from 2.8 x 1.1 m to 1.7 x 1.1 m, decreases the density of the roots less than 1 mm in the 200-400 mm range and increases them in the 400-600 mm range (Kubecka, 1968). Higher density plantings increase competition and encourage the vines to develop deeper roots, thereby using soil water unavailable to vines of a wider spacing (Kubecka, 1968; Matuzok, 1977). Planting grass strips may also result in deeper rooting of vines (Richards, 1983).

Tillage influences rooting of woody perennials. Shallow cultivation at regular intervals results in 'root-free' zones in upper layers (Buttrose and Mullins, 1968). This practice simulates root pruning, which has been demonstrated to decrease shoot growth 50-75% within seven days (Buttrose and Mullins, 1968), while increasing the growth and yield the following year (Melkonyon,

1973). No increase in root growth was observed after root pruning (Fick, et al., 1971; Richards and Rowe, 1977a). Root growth is greatest under no-till conditions (Steinberg, 1972).

Mulching and irrigation affect root growth in woody perennials. Increased root, shoot, and fruit production on grapevines (Chlkhortishvili and Bekauri, 1979) and in peaches (Cockroft and Wallbrink, 1966) occurs as a direct result of mulching, with the percentage of roots above 0.40 m increasing by 50-80%. Irrigation influences rooting and while crops are generally nonirrigated in Oregon, summer rainfall serves a similar purpose. The effects are dependent upon edaphic factors such as soil type, texture, moisture, nutrition, and temperature. Optimum soil temperatures for grapevine root growth occurs at 30 °C (Winkler, et al., 1974), while optimum soil temperature for root growth in other woody perennials is 6 °C (Nightengale, 1935; Rogers, 1939). Springtime root growth occurs at the surface, while winter root growth is much deeper (Rogers, 1939). Nutrition plays a role in rooting. Studies demonstrate the need for a continual supply of calcium and boron (Haynes and Robbins, 1948). Boron deficiencies distort roots and root tips die (Bode, 1939). Root branching is dependent on nitrogen and phosphorus (Duncan and Ohlge, 1958; Drew and Saker, 1975). Water stress affects shoot growth more than root growth, and has a very strong influence on rooting patterns (Richards and Cockroft, 1974). Richards and Cockroft (1974) demonstrated that soil water potentials lower than -50 kPa have little effect on root elongation rates. Because of their propensity to form deep roots and their insensitivity to low soil moisture, grapevines are

considered drought tolerant (Freeman and Smart, 1976). Studies also demonstrate an increase in length and number of white roots present when under water stress which enables grapevines to exploit a greater area of soil (Hofacker, 1977; Kmoch, et. al., 1957).

Compacted zones affect rooting depth and distribution in the soil. Studies of grapevines and peaches show fewer roots in the traffic lane, with numbers as low as 10% of total roots present (Gabovic, 1963, Richards and Cockroft, 1974). Increases in soil bulk density result from compaction, and root growth decreases. Grapevine roots penetrate soils with bulk densities of 1.1-1.2 g cm³. Rooting decreases in soils with a bulk density of 1.5 g cm⁻³ and higher (Richards and Cockroft, 1974). Pentrometer studies show resistance of 2500-3000 kPa prevents root elongation (Taylor and Gardner, 1963). Planting grass in orchards and vineyards may reduce soil compaction, but decreased rooting of vines occurs under grass strips (Morlat, 1981; Lombard et. al., 1988). Compaction reduces soil pore space, thereby reducing the amount of aeration to the roots. Few roots grow in soils with air contents below 5% air pore space (Taylor, 1949), with maximum vigor occurring at approximately 10% air pore space (Morita, 1955). Root restrictions may occur as a result of air composition around the roots. Air of approximately 10% O₂ is adequate for cotton and soybeans (Huck, 1970). Grapevine shoot growth decreases as soil air O₂ content decrease from 20% to 0, indicating grapevines may be more sensitive to poor aeration than other species (Iwasaki, 1972).

C. Soil Management Factors

Water use of grapevines is dependent on cultural, meteorological and edaphic factors (Winkler, et al., 1974; Smart and Coombe, 1983). Evapotranspiration rates depend on meteorological conditions when the vine is supplied with adequate water. Stomates control transpiration when transpiration rates exceed water uptake rates (Smart and Coombe, 1983). Grapevines exhibit a greater degree of control over transpiration when compared to other crops (Doorenbos and Pruitt, 1977). Estimates of grapevine crop coefficient (kc) values in late September and October are: 0.45 (April), 0.6 (June), 0.7 (July-September), 0.6 (October), 0.35 (November) (Doorenbos and Pruitt, 1977). Peak transpiration occurs during flowering to veraison (Veihemeyer and Hendrickson, 1951), with maximum transpiration estimates of 5.9 mm day^{-1} (Smart and Coombe, 1983).

Soil texture affects crop ET rates by affecting water retention and rooting. Estimates of available water in varying soil textures are 30 mm m^{-1} for sand, to 160 mm m^{-1} for clay (Smart and Coombe, 1983). Water infiltration capacity can be limited by compaction, in-washing of colloids, and surface swelling. Limited infiltration may limit rooting. Rooting studies in coarse sand show rooting to occur to 6 m, while in heavy soils rooting is restricted to the top 0.1-0.7 m (Van Zyl and Weber, 1977). Root weight increases with increasing water availability (Magriso, and Tonochev, 1971), but other studies show root weight to increase with decreasing water availability due to root extensions in search of soil water (Hofacker, 1977).

Soil media influences root growth, with coarse media producing coarse brittle roots that demonstrate little branching. Plants in other media have slender flexible roots with greater branching with differences being attributed to varying moisture contents (Livingston and Free, 1917; Long, 1932).

III. GRASS-GRAPEVINE INTERACTION

A. Competition

Interference is a term used to categorize the types of interactions occurring among organism in a population. The types of interactions were categorized by Burkholder (1952) and consist of both negative interactions, such as allelopathy and competition, and positive interactions, such as mutualism and protocoooperation.

Competition is the mutually adverse effects of organisms (plants) which utilize a resource in short supply (Barbour, 1980) and is an important reason for discouraging the use of grass cover crops in cropping systems. Competition is primarily for nutrients (nitrogen) and water (Vomocil, 1985). Competition between woody perennials and grass species show competition to occur for light, water, and nitrogen (Mouat and Walker, 1977; Delver, 1980; Atkinson and White, 1980; Haynes and Goh, 1980; Messenger, 1976; Neely, 1984). Vineyards planted with ryegrass strips require rates of nitrogen to be increased by 50 kg/ha, with $\text{NO}_3\text{-N}$ being notably higher in the surface soil of the nongrassed plots. Surface soil (0-10 cm) with grass contains higher levels of calcium and magnesium, and less $\text{NO}_3\text{-N}$ with no significant effect on the growth of apple trees (Haynes and Goh, 1980). Similar studies on

the effects of grass sods on nutrient content in perennial cropping systems show decreased nitrogen levels and yield in the presence of grassed down strips while other minerals, such as calcium and magnesium, are increased (Mouat and Walker, 1968; Bailey and Gupta, 1973; Robinson and O'Kennedy, 1978; Neely, 1984; Nielson and Hogue, 1985). Applications of nitrogen on the grassed plots increases growth and vigor of the trees (Neely, 1984).

Grass cover crop suppression with herbicide increases vigor and yield in perennial cropping systems (Robinson and O'Kennedy, 1978; Atkinson and Crisp, 1986). Suppressing grass strips showed no significant difference, when compared to unsuppressed grass, in mineral content in the 0-0.1 m zone (Haynes and Goh, 1980). Soil management, such as cultivation, grass covers, and irrigation, influences root distribution and nutrient uptake, demonstrating soil management to be more influential than additions of nitrogen (Atkinson and White, 1980).

Competition for nitrogen in surface layers between grass and perennial crops forces the perennial crop to root deeper than in nongrassed plantings (Morlat, 1981).

E. Cultural Practices and Competition

Cultural practices influence physiological responses of vines. The effects of irrigation (Wilson, 1985; Kobayashi, et al., 1963) on yield in vineyards when planted with grass strips compared to clean cultivated strips (Kenworthy, 1951; Veihmeyer and Hendrickson, 1950) show clean cultivated rows to have higher yield.

The degree to which water stress affects growth is a function

of the stage of growth of the vine and the rate of the onset of water stress, with water status being crucial from flowering to berry growth of 4 mm in diameter (Kobayashi, et. al., 1963; Smart and Coombe, 1983). Young tissues (shoot internodes and tendrils) are sensitive to changes in water potential (Kobayashi, et. al., 1963). Severe water stress results in necrotic areas on the leaf margin, and death occurs to young shoots and leaves (Van Zyl and Weber, 1977).

The effect of grass cover crop management by mowing and chemical suppression (Van Huyssteen and Weber 1980a; Haynes and Goh, 1980; Morlat, et al., 1981) reveals rooting, growth, and yield to be greatest under herbicide strip management, with suppressed and mown sod, respectively, decreasing crop yields. Festuca arundinacea grass strips in vineyards reduce vine root development; more specifically, the grass reduces the number of white roots present which are thought to be the most efficient absorbers of moisture (Morlat, 1981). Thick root development is also inhibited by Festuca arundinacea cover, and grapevine roots penetrate to deeper depths (Morlat et. al., 1981).

F. Competition, Quality, and Yield

Competition for water in unirrigated Oregon vineyards can become severe as summer progresses. Rainfall becomes limited and high temperatures increase transpiration. Cool season grasses become dormant when soil moisture becomes scarce and temperatures increase (Beard, 1983; Cook, 1985). Competition occurring before grasses go dormant can deplete soil moisture from the surface layers and force the vine to draw from reserves deep in the soil.

As the season progresses, the vines may become water-stressed (Smart and Coombe, 1983). Yield, vegetative growth, and fruit quality of the grapevine are highly correlated to soil water content over the season (Van Rooyen, et al., 1980). Cluster and pruning weights are suppressed by grass strips planted to the base of the vine, and 1.5 m out from the base of the vine (Brenner, personal communication; Stevenson, et al., 1986) along with reduced yields and late maturation (Becker, 1986; Muller, 1986). Losses in yields are attributed to reduced fruit set (Hardie and Considine, 1976) when vines are stressed for water before veraison (Veihmeyer and Hendrickson, 1950; Van Zyl and Weber, 1977). Drier soil regimes result in improved sugar:acid ratios. Twenty-five percent soil moisture and water stress during flowering and phase I of berry development reduces berry size and leads to high tartaric acid at veraison (Van Zyl, 1983). Improved sugar:acid ratios are attributed to decreased shoot growth, reduced canopy density, and photosynthate increases by interior leaves (Hardie and Considine, 1976) due to slight water stress. Severe water stress can delay sugar accumulation through reduced photosynthesis and defoliation (Smart and Coombe, 1983; Hardie and Considine, 1976; Hardie, 1980). Irrigation decreases the quality of the grapes by increasing acidity (Kliwer and Lider, 1968; Freeman, 1980), and lowering °Brix (McCarthy and Coombe, 1985). Increased canopy leafiness reduces light penetration (Smart, 1974; Smart, 1982) delaying harvest and maturation (Smart, 1982; Hardie and Considine, 1976), and reduces fruit color (Veihmeyer and Hendrickson, 1950; Freeman, 1983; McCarty, 1984).

G. Noncompetitive Effects

Interference includes all forms of reactions by one plant that prove deleterious to another (Radosevich and Holt, 1983). Competition and allelopathy are types of interference. Allelopathy is defined as either a positive or negative effect of one plant on another (Molisch, 1937; Rice, 1983).

Allelopathy is implicated in several plant interactions such as weed-crop relationships (Schreiber and Williams, Jr., 1966; Bell and Koepe, 1972; Colton and Einhellig, 1980; Bhowmik and Doll, 1982; Bhowmik and Doll, 1984; Bell and Koepe, 1972; Rose, et al., 1984; Walker and Jenkins, 1986; Schafer and Garrison, 1986). Allelopathy has also been implicated for negative effects on growth of woody perennials associated with turfgrass. Field responses of woody perennials to competition from turfgrass indicate factors other than competition for nutrients to reduce growth (Whitcomb, 1972; Whitcomb and Roberts, 1973; Nielson and Wakefield, 1978; Fales and Wakefield, 1981; Shribbs, et al., 1986). Rye reduces grapevine growth under luxury conditions (Cubbon, 1925). Tall fescue has been studied for allelopathic potential (Morlat, 1981; Peters and Zam, 1981) and is shown to reduce rooting of grapevines (Morlat, 1981), and inhibit germination of birdsfoot trefoil (Peters and Zam, 1981; Peters, 1968; Luu, et al., 1982).

H. Mechanisms

Roots of higher plants may exude substances harmful to the growth of roots of other plants (Schreiner and Reed, 1907). Root

exudation studies show these exudates to be produced in small amounts (Woods, 1960). Mechanisms of release include release from decomposing plant material via weathering and soil microbes (Rice, 1964; Kimber, 1973) and leaching from plant parts by rain, dew, or irrigation (Tukey, 1969; Tukey and Morgan, 1963; Mitchell, et al., 1961). Distinguishing between healthy and harmful root residues is difficult (Schreiber and Williams, Jr., 1907; Woods, 1960; Garb, 1961). Evidence shows that decomposing plant residues are phytotoxic enough to reduce productivity, and can devastate succeeding crops (Holland, 1962). Rates of exudation (Rovira, 1956; Rovira, 1959; Widdawson, 1958; Katznelson, et al., 1954; Katznelson, et al., 1955) and leaching (Mitchell, 1968; Kozel and Tukey, 1968; Tukey and Morgan, 1963, Bhan, et al., 1959) are dependent upon environmental factors. Leachate from decayed plant residues contains substances considered to be potentially phytotoxic, and are considered a factor in reducing growth (Newman and Miller, 1977; Bell and Koeppe, 1972; Bhowmik and Doll, 1984, Bhowmik and Doll, 1982; Menzies and Gilbert, 1967; Walker and Jenkins, 1986; Shafer and Garrison, 1986). The effects of leachate and exudates can be either direct or indirect. The plant can be directly affected by the substance, or the substance can be altered to a more phytotoxic substance by soil microbes. The substance may alter the soil environment which in turn may alter the population of soil microbes. Environmental alterations may be considered allelopathic if the result affects plant growth and behavior (Rice, 1983; Tukey, 1969).

Although allelopathy has been considered a factor in reduced

growth in many systems, few allelopathins have been identified (Davis, 1925; Massey, 1925). Many compounds from exudates and leachates have been identified, including alkaloids (Levitt and Lovett, 1985), terpenes and phenolics, sugars, amino acids, peptides, enzymes, vitamins, organic acids, nucleotides, fungal stimulants, inhibitors, and attractants (Rovira, 1969). Plant hormones and carbohydrates have also been identified in plant exudates and leachates (Kozel and Tukey, 1968). The role these substances play in plant interactions has not been studied well enough to draw conclusions on their allelopathic potential under field conditions.

Chapter 3

EFFECT OF COOL SEASON GRASSES ON GRAPEVINE
(Vitis vinifera) GROWTH AND DEVELOPMENT

ABSTRACT

Two greenhouse experiments were performed to investigate the effects of grass growth of 4 cool season grass species (Lolium perenne L., Agrostis tenius L., Festuca arundinacea L., and Festuca ovina L.) on grapevine (Vitis vinifera 'Pinot Noir') growth and development under luxury nutrient and water supply. In the first experiment grass seed and uncalled dormant grapevine cuttings were planted simultaneously in 4 L sand-filled pots. The vigorous rooting grass species gave greater grapevine shoot weights, but lower grapevine root weights. Differences were a function of the growth habit of the grass. Dense rooting grasses provided benefits to the grapevines by preventing water and possibly nutrients from being leached. In the second experiment, perennial ryegrass (L. perenne cv. 'Elka') was established in 15 liter sand and peat-filled pots before uncalled dormant grapevine cuttings were planted. Nutrients and water were supplied at luxurious levels. Root initiation and growth of cuttings grown with established grass was inhibited. Only 25% of the cuttings grown with grass had budburst and initiated rooting, while there was 100% rooting occurrence on the cuttings in the no grass treatments. The grass modified the soil environment when established prior to grapevine cuttings, and rendered the soil unfavorable for root initiation and growth. Allelopathy may be involved.

INTRODUCTION

Cool season turfgrass species are recommended as cover crops in perennial cropping systems in the Pacific Northwest to prevent soil erosion (Vomocil, 1985; Butler 1986). Other advantages include increased traffic-carrying ability, a cool humid atmosphere during summer months, and quick extraction of late season moisture. Possible disadvantages are increased frost hazard, increased pest problems, allelopathy, and competition for nitrogen and water (Vomocil, 1985; Butler, 1986; Putnam, 1986).

Plant-plant or plant-environment interactions can be positive, negative, or neutral. Competition and allelopathy are types of negative interference (Burkholder, 1952). Allelopathy refers to stimulated or inhibited growth and behavior of associated plants but is not a function of competition (Molisch, 1937; Rice, 1983), and occurs through the release of substances into the immediate environment. These substances may directly affect neighboring plants, or indirectly affect them through alterations to the environment (Rice, 1983).

Grapevines show reduced rooting in upper soil layers under grass cover (Morlat et al., 1981; Lombard, et al., 1988). This has been attributed to competition for nitrogen and soil water (Morlat, 1981). Allelopathy has been implicated as a factor in the growth reduction of plants associated with turfgrasses (Whitcomb, 1972; Whitcomb and Roberts, 1973; Peters and Zam, 1981).

Two greenhouse studies were initiated to observe the effect

of grass interference on the growth of uncallused two-node 'Pinot Noir' grapevine cuttings. Plants were supplied with luxury levels of nutrients and water. Growth parameters were measured and inhibition of growth was thought to be a result of allelopathy.

MATERIALS AND METHODS

1987 Greenhouse Experiment

A completely randomized design with one no grass and five grass treatments was used in the experiment, grasses being Lolium perenne L. cv. 'Elka', L. perenne L. cv. 'Derby', Agrostis tenuis L. cv. 'Highland', Festuca ovina L. cv. 'Covar', Festuca arundinacea L. cv. 'K-31'. Each treatment was replicated 20 times.

Set up was on 4 April 1987. Uncallused two-node dormant grapevine (Vitis vinifera 'Pinot Noir') cuttings were placed in 4 l PVC pots filled with 30-grain fine quartz mason sand. Each grass was seeded at a rate of 44.8 kg ha^{-1} (0.81 g pot^{-1}). Pots were watered daily with 200 mls of tap water. Mean greenhouse temperatures were 18.9°C at day and 13.3°C at night. Peter's 10-20-10 fertilizer nutrient solution was applied in 200 ml aliquots 3 times per week. Concentrations of nutrients in the solution were 175 ppm total N, 85 ppm P, and 325.5 ppm K (equivalent to 19 kg ha^{-1} N, 9.3 kg ha^{-1} P, and 35 kg ha^{-1} K). After grapevine budburst, nutrient solution applications were increased to a daily basis.

By early June, at the sixth node stage in development of the grapevines, grape leaves showed signs of nutrient imbalances which were confirmed by plant analysis. Leaves began to cup under, and had interveinal chlorosis and necrosis. Shoot tips were also necrotic. Results showed high potassium levels and low calcium, magnesium and zinc. An alternative solution consisting of 58 ppm N, 28 ppm P, and 108.5 ppm K was used three times a week until

harvest. A micronutrient solution containing sulphur, boron, copper, iron, manganese, molybdenum, and zinc was applied as a supplement in 200 ml aliquots 3 times per week. In addition, separate solutions of calcium nitrate $[\text{Ca}(\text{NO}_3)_2]$ and magnesium sulfate $[\text{MgSO}_4 \cdot 7\text{H}_2\text{O}]$ at concentrations of 49 ppm each were applied 3 times a week. After 2 weeks the new growth appeared healthy.

Shoot growth was measured about every two weeks during the latter part of the experiment. At harvest, final shoot length, shoot weight, leaf weight, node number, cutting weight, root weight, grass shoot weight, and grass root weight were measured. Samples were dried in a tunnel dryer at 40.6°C for 48 hours for dry weights. Analysis of variance, and regression and correlation analyses were performed.

1988 Greenhouse Experiment

In 1988 a similar greenhouse study with completely randomized treatments of grass alone, grapevines alone, and grass and grapevine cuttings together was used. Unrooted two-node dormant 'Pinot noir' grapevine cuttings were planted in a standard density of established (25-38 mm high at density of 1848 plants m^{-2}) perennial ryegrass (L. perenne var. 'Elka') in 15 l buckets filled with sterilized sand-peat (1:1). Delmhorst cylindrical gypsum blocks (Model GB-1 of 22.2 mm diameter x 11.3 mm height) were placed at three depths (0.08 m, 0.15 m, and 0.30 m) in three buckets from each treatment. Gypsum block readings were taken three times per week with a Delmhorst KS-1 Soil Moisture Tester. The plant system was watered to saturation with daily

irrigations. Nutrient analysis of the soil media was conducted before and after the experiment by the OSU Soil Testing Lab. Total nitrogen, phosphorous, extractable bases (Ca, Mg, K, and Na), boron, pH, and cation exchange capacity were determined before the experiment, and pH, P, B, and extractable bases (Ca, Mg, and K) were determined after the experiment under grass and no grass treatments. Fertilizer solution of the same composition as 1987 was applied daily.

The experiment was established on 20 February 1988. Grass was mowed when it reached a height of 0.15 m. Clippings were weighed. Two destructive harvests were performed at four-week intervals, with the first occurring 8 weeks after set up. The same measurements were made as in the 1987 experiment at each harvest date. Also, total grapevine root length was estimated using a modified line intersect method (Tennant, 1975; Goubran and Richards, 1979), and grape root density was determined from root dry-weight and pot-volume measurements. Plant samples were dried in a 70 °C oven for 48 hours. Nutrient analysis of leaf petioles was performed at the last harvest on 17 June 1988.

Carbon dioxide concentration of the soil under two grass and no grass replicates was determined at the end of the experiment. Rubber tubing (50 x 2 mm i.d.) was placed into the soil until flush with the surface, and the exposed end sealed with a septum to prevent contamination by ambient air. The sealed tubing was allowed to equilibrate with the soil atmosphere for 5 days. Ten ml samples were then extracted from each sealed tube in syringes and analyzed for CO₂ concentration in a Beckman Infrared Gas

Analyzer with N₂ carrier gas (Model # 865). This was repeated 3 times over 3 days. Analyses of variance, and regression and correlation analyses were used to analyze all data.

RESULTS AND DISCUSSION

1987 Greenhouse Experiment

Ryegrass and bentgrass species germinated four days after seeding while fescue species germinated 15 days after seeding. Grass species that were quick to establish had the greatest total biomass, root weights, and root:shoot ratios (Table 3.2). Grapevines grown with grass species having the greatest dry root weight had the greatest dry shoot weight (Table 3.3) the greatest shoot growth rate (Table 3.4), and the lowest dry root weight. Grass species with high root:shoot ratios provided grapevines with low root:shoot ratios (Table 3.2).

Despite problems with the nutrient balance (Table 3.5) of the grapevines, grass growth habit was the factor having the greatest influence on grapevine growth. Dense rooting grass species increased grapevine shoot growth rates and shoot weights. This could be a result of the grass roots preventing some water, and possibly nutrients, from being leached. Allelopathy was not an obvious factor in grapevine growth reductions.

1988 Greenhouse Experiment

Grapevine growth was significantly reduced under grass (Table 3.6, Table 3.7). Significant correlations were found for root length and leaf area, root length and shoot length, and root weight and leaf weight (Table 3.8).

Grass plant density (Table 3.9), clipping weights (Table 3.10), and soil moisture content (Table 3.11) were not significantly different between treatments. Soil temperature in the no

grass treatment had greater maximum-minimum ranges, but differences were small (Fig. 3.1). Nutrient levels were within normal ranges with the exception of low zinc and copper (Table 3.12). Nutrient analysis was only performed on the no grass treatments because of lack of leaves on the grapevines in the grass treatments. Soil nutrient analysis results (Table 3.13) show that the acidity of the soil media decreased under both plant treatments, while P, B, and extractable bases increased under both treatments. P and K levels were greater under no grass treatments.

Dramatic differences in rooting, establishment, and growth of grapevine cuttings in the 1988 greenhouse experiment show grape root initiation and growth to be inhibited in the presence of perennial ryegrass (Fig. 3.2). Water and nutrients were applied at luxury levels to the plants and can be eliminated as factors in growth reduction. Six of the 24 cuttings planted in ryegrass had budburst, with root growth being absent in the upper 150 mm of soil and greatly reduced compared to bareground treatments. All cuttings in the bareground treatments had budburst and root initiation, while rooting was present in the top 10 mm of soil media.

Carbon dioxide measurements of the soil under grass and no grass treatments showed CO_2 levels to be greater under no grass treatments (Table 3.14). CO_2 concentrations under field conditions on a calcareous silt-loam soil showed CO_2 to be significantly higher in soils under grass cover, and was implicated as a factor in the reduced rooting of trees in the upper soil layers in the presence of grass cover crops (Howard, 1924).

CO₂ concentrations of soil are estimated to be 0.001-0.05 m³ m⁻³, and can be increased by increased soil temperature and soil moisture, and by plant cover (Glinski and Stephniewski, 1983). The higher CO₂ concentrations under no grass treatments in the greenhouse could result from less diffusion of CO₂ under grass, higher moisture under no grass, or by respiration of the grapevine roots.

The establishment of the grass prior to root initiation of the grape cuttings rendered the soil media unfavorable for grapevine root initiation. 'Space capture' is an important competitive strategy of successful weed species (Dawson, 1965; Harper, 1977). Space refers to all resources, and their interactions, as a unit in a given area that is required for plant growth (Radosevich and Holt, 1983). The early occupation of available space resulted in the grass having an advantage over the cuttings. The addition of luxury supplies of water and nutrients did not enable the cuttings to overcome the inhibition.

CONCLUSIONS

Grass affects grapevine growth and development in greenhouse pot culture. The effect is a function of the growth habit of the grass and the time and order of establishment. Grasses which are slow to germinate and become established give the grapevine a longer grass-free period in which to initiate rooting than grass species which are quick to germinate and become established. Order of establishment is also important to reduce competitiveness of the grasses. Establishment of grasses first results in inhibition of callus formation and rooting of grapevine cuttings. Allelopathy may be involved.

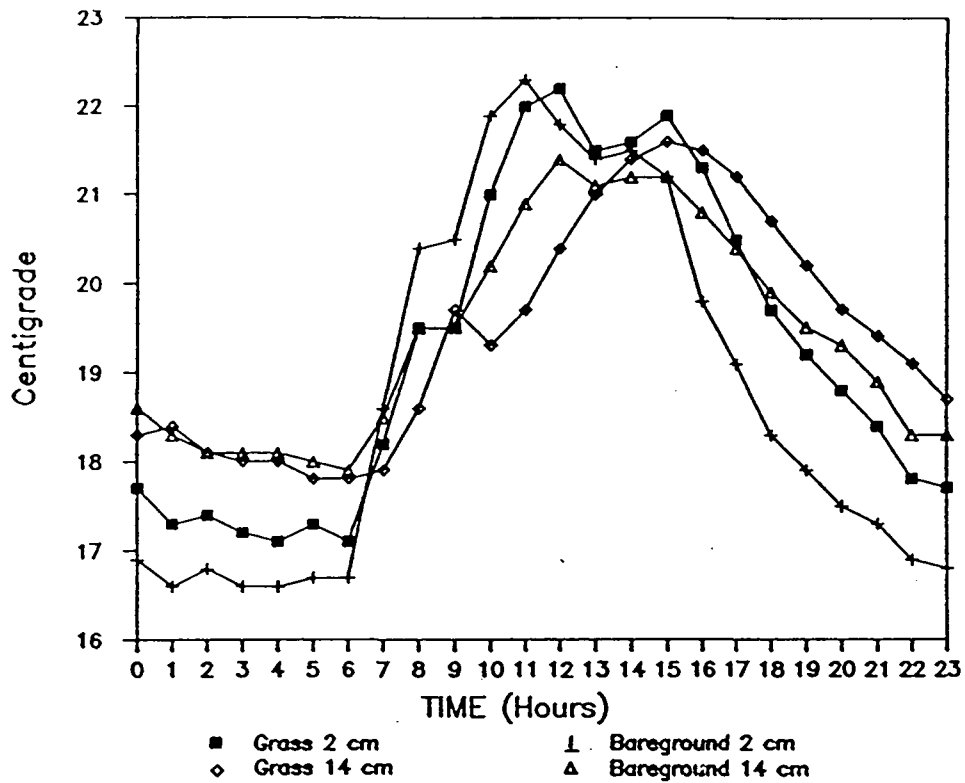


Figure 3.1. Mean soil temperature readings for 24 hour period averaged over 3 days under grass and no grass treatments at 2 and 14 cm depths in greenhouse pot culture, 1988.



Figure 3.2. Rooting of grapevine cuttings grown under grass and no grass in greenhouse pot culture, 1988.

Table 3.1. Components of plant growth measured in the 1987 and 1988 greenhouse study, adapted from Patterson (1982).

Component	Formula
<u>Relative growth rate</u> : Reflects efficiency of plant at producing new material.	$\ln W/T = \ln W_2 - \ln W_1 / T_1 - T_2$
<u>Leaf Area Ratio</u> : Reflects leafiness of plant and represents photosynthetic area at a harvest interval.	$LAR = A_l / W$
<u>Leaf Area Index</u> : Measurement of canopy area relative to a constant ground area.	$LAI = A_l / A_g$
<u>Root:Shoot Ratio</u> : Indicates proportion of biomass allocated to roots and shoots.	$R/S = \text{Root dry wt.} / \text{Shoot dry wt.}$
$T = T_2 - T_1$	length of harvest interval
W_1, W_2	total dry weight at beginning and end of harvest interval
R	root dry weight at end of harvest interval
S	shoot weight at end of harvest interval
A_l, A_g	leaf area, ground area
T	time (days)
W	dry weight (g)
\ln	natural logarithm
A	Area (cm^2)

Table 3.2. Vegetative growth of various grass species grown in greenhouse pot culture grown with Pinot noir grapevines, 1987.

Treatment	shoot wt.(g)*	root wt.(g)*	total biomass(g)*	root:shoot ratio
Elka perennial ryegrass	6.4	14.9	21.3	2.3
Covar sheep fescue	4.2	3.1	7.3	0.74
K-31 tall fescue	8.6	3.8	12.4	0.40
Derby perennial ryegrass	6.4	18.4	24.8	2.9
Highland bentgrass	8.8	18.1	27.0	2.0
Standard Error of Mean	0.74	2.1	2.4	0.68
LSD (0.05)	1.8	5.2	5.9	1.7

* Weights represent dry weight measurements

Table 3.3. Effect of various grass species grown in greenhouse pot culture on the growth of Pinot noir vines, 1987.

Treatment	leaf wt.(g)*	shoot wt.(g)*	node number	root wt.(g)*
Elka perennial ryegrass	10.29	15.91	33.84	4.67
Covar Sheep fescue	9.60	13.92	38.15	5.17
K-31 tall fescue	7.65	12.25	38.42	4.80
Derby perennial ryegrass	8.97	14.16	36.95	3.72
Highland bentgrass	10.33	16.67	38.35	4.40
No grass	8.05	13.12	40.65	4.12
Standard Error of Mean	0.82	1.44	1.49	0.53
LSD (.05)	2.00	3.52	3.62	1.30

* Weights represent dry weight measurements

Table 3.4. Effects of various grasses grown in greenhouse pot culture on the growth of Pinot noir vines, 1987.

Treatment	total biomass (g)	root:shoot ratio	SGR ^a (cm day ⁻¹)
Elka perennial ryegrass	38.86	0.35	5.0
Covar sheep fescue	37.99	0.46	4.4
K-31 tall fescue	31.78	0.43	3.3
Derby perennial ryegrass	36.08	0.27	4.7
Highland bentgrass	39.87	0.26	5.8
No grass	34.26	0.35	3.0
Standard Error of Mean	2.78	0.04	0.46
LSD (0.05)	6.78	0.10	1.11

^a Shoot growth rate over two week interval

Table 3.5. Grape petiole analysis of Pinot noir grapevines grown with various grass species in greenhouse pot culture, 1987.

	Control	Elka	Covar	K-31	Highland	Rating ^a
	<u>g.g⁻¹.10⁻² concentration in dry wt.</u>					
N	0.83	1.01	0.84	0.83	0.82	Low
P	0.49	0.59	0.49	0.45	0.49	High
K	6.75	5.94	6.63	7.08	6.88	Very high
S	0.20	0.30	0.22	0.20	0.24	Normal
Ca	0.51	0.65	0.60	0.57	0.65	Low
Mg	0.14	0.18	0.19	0.16	0.15	Low
	<u>ug.g⁻¹ concentration in dry wt.</u>					
Mn	133	118	132	134	143	Normal
Fe	51	31	31	37	26	Normal
Cu	10	9	9	9	9	Normal
B	71	66	73	80	76	Normal
Zn	23	30	36	24	34	Low

^a Rated according to fourteen year average of grape petiole analysis for all counties in Oregon.

Table 3.6. Shoot growth rate of Pinot noir vines grown in greenhouse pot culture with and without perennial ryegrass, 1988.

Treatment	shoot growth rate at various intervals					
Interval ^a	1	2	3	4	5	6
			cm/day			
Grass	0	0	0.11	0.19	0.18	0.13
Bareground	0.51	0.68	1.05	2.24	4.19	4.68
Standard Error ^b	0.02	0.02	0.11	0.20	0.25	0.26
LSD (0.05)	0.09	0.06	0.32	0.45	0.61	0.64

Values represent mean of 5 replications

^aInterval 1=25/3-4/4; Interval 2= 4/4-11/4; Interval 3= 11/4-18/4; Interval 4= 18/4-25/4; Interval 5=25/4-3/5; Interval 6= 3/5-10/5.

^b Standard Error of Mean

Table 3.7. Effects of 'Elka' perennial ryegrass on growth parameters of Pinot noir grapevines in greenhouse pot culture, 1988. Grass planted 20 February, grapevines planted 28 February. Harvest 1 = 18 April, Harvest 2 = 17 May.

Treatment	leaf area (cm ²)	LAR ^a (cm ² g ⁻¹)	LAI ^b	root density (mm/cm ³)	root length (cm)	r:s ratio ^c
<u>Grass</u>						
Harvest 1	3.12	0.005	0.006	0.11	19.88	0.02
<u>No grass</u>						
Harvest 1	35.95	0.015	0.065	1.50	261.48	3.60
Standard Error ¹	3.36	0.003	0.006	0.001	22.21	0.52
LSD (0.05)	9.57	0.010	0.017	0.004	63.3	1.49
<u>Grass</u>						
Harvest 2	17.21	0.007	0.031	0.38	65.56	0.33
<u>No grass</u>						
Harvest 2	136.48	0.018	0.247	6.09	1059.12	0.30
Standard Error ^d	8.76	0.004	0.017	0.007	124.5	0.19

^aLAR = leaf area ratio

^bLAI = leaf area index

^cr:s = root:shoot ratio

^dStandard Error of Mean

Table 3.8. Regression equations, R^2 values, and r values for growth parameters of Pinot Noir grapevines as influenced by perennial ryegrass. (Grass planted: 20/2, grapevines cuttings planted: 28/2)

Variables (X,Y)	Equation	R^2	r
Harvest 1 (18/4)			
Root length, Shoot length	$y = 1.15 + 0.061x$	0.78	0.87
Root weight, Leaf weight	$y = 0.13 + 0.306x$	0.24	0.49
Root length, Leaf area	$y = 2.23 + 0.11x$	0.66	0.81
Harvest 2 (17/5)			
Root length, Shoot length	$y = 7.59 + 0.104x$	0.86	0.92
Root weight, Leaf weight	$y = 0.214 + 3.15x$	0.93	0.96
Root length, Leaf area	$y = 11.3 + 0.106x$	0.84	0.92
Significance (0.05)			0.80

n=5

Table 3.9. 'Elka' perennial ryegrass plant density grown in greenhouse pot culture grown with and without Pinot Noir grapevines, 1988.

Treatment	Estimated density	Actual density ^a
Grass-grapevine	1848 plants/m ²	1900 plants/m ²
Grass-monoculture	1848 plants/m ²	1950 plants/m ²
Standard Error of Mean		89.2

^a Determined by counting the number of individual grass plants per 10 cm² in 5 replications of each treatment

Table 3.10. Mean grass clipping weight of 'Elka' perennial ryegrass grown in greenhouse pot culture alone and with Pinot noir grapevines 1988 (planting date: 20 February 1988).

Treatment	7/3	15/3	22/3	(g) 3/4	11/4	25/4	3/5
Grass + Vine	0.080	0.34	0.60	1.61	1.21	0.69	1.07
Grass	0.085	0.34	0.56	1.73	1.33	0.87	1.53
Standard Error of Mean	0.010	0.02	0.02	0.33	0.08	0.06	0.31
LSD (0.05)	0.02	0.04	0.05	0.93	0.24	0.28	0.87

Table 3.11. Mean gypsum block readings of blocks at depths of 7.6, 15.2 and 30.5 cm in greenhouse pot culture under grass, grass + grapevines, and grapevines, 1988.

Treatment	moisture tension (kPa) ^a		
	Depths: 7.6cm	15.2cm	30.5cm
Grass	40.5	41.5	40.5
Grass + Grapevine	40.5	43.6	43.6
Grapevine	41.5	44.6	40.5
Standard Error of Mean	0.71	3.04	3.04
LSD (0.05)	2.0	8.1	9.1

^aValues represent means of weekly readings over the entire experimental period, taken prior to irrigation.

Table 3.12. Grape petiole analysis of Pinot noir grapevines grown in pot culture with no grass, 1988.

	Concentration	Rating ^a
N ($\text{g} \cdot \text{g}^{-1} \cdot 10^{-2}$)	1.14	Normal
P	0.29	Normal
K	3.78	High
S	0.27	Normal
Ca	1.32	Normal
Mg	0.42	Low
Mn ($\mu\text{g} \cdot \text{g}^{-1}$)	433	Normal
Fe	61	Normal
Cu	2	Low
B	61	High
Zn	17	Low

^aRating based on fourteen year average of grape petiole analysis for all counties in Oregon

Table 3.13. Soil analysis of greenhouse media [sand:peat (1:1)], used in pot culture experiment prior to use, after use under no grass, and after use under grass, 1988.

	Prior to use	No Grass	Grass
pH	4.6	5.5	5.4
P (ppm)	7.0	32.0	20.0
K (ppm)	78.0	176.0	66.0
Ca (meq/100 g)	4.5	5.5	5.6
Mg (meq/100 g)	2.4	2.8	2.8
Na (meq/100 g)	0.4		
B (ppm)	0.39	0.90	0.38
Total N	0.06		
NO3-N	20		
NH4-N	2.9		
CEC	10.3		

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Table 3.14. Soil CO₂ measurements in greenhouse pot culture under grass and no grass treatments, 1988.

Treatment	CO ₂ Concentration m ³ . m ⁻³
Grass	0.00206
No Grass	0.00440
Standard Error of Mean	0.00037
LSD (.05)	0.00101

Values represent the means of 2 replications over a sampling period of 3 days

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Chapter 4

WATER USE OF COOL SEASON GRASSES

ABSTRACT

A 2 year field study was performed to investigate the consumptive water use of 4 cool season grass species (Lolium perenne L., Agrostis tenuis, Dactylis glomerata, and Festuca arundinacea) in the Willamette Valley, Oregon under low maintenance conditions. Soil water content was measured every 7-10 days during April-July in 1986, and April-August in 1987 with a neutron probe moisture meter. Evapotranspiration of the grasses was determined using the soil water balance method with the water depletion and rainfall data. There were no significant differences in the seasonal evapotranspiration and the total depletion of soil water among the grass species, with all grass species having higher evapotranspiration rates than bareground in both years. In late summer months, evapotranspiration of grass plots and bareground was not significantly different. Root density and water depletion were greatest between 0-0.15 cm. Correlations were high between water depletion per layer and root density for all species except bentgrass (A. tenuis cv. 'Highland').

INTRODUCTION

The Willamette Valley receives an average of 760-1020 mm of precipitation per year, with most occurring in the fall through early summer. Late summer months are dry, with temperatures reaching 40 °C.

In Oregon, trees and vines are nonirrigated; growers instead rely on stored soil moisture during the hot, dry periods. Planting grass cover crop strips in orchard or vineyard alleys, or maintaining bareground with herbicides, are common management practices in orchards and vineyards. Grass strips are recommended to reduce soil erosion, increase traffic-carrying ability, reduce compaction, and extract late-season moisture (Vomocil, 1985). Disadvantages of sods might be increased frost hazard, increased pest refugia, and competition for nutrients, light, and water (Vomocil, 1985). Grass cover crops can increase water stress during dry summer months by competing for stored soil moisture. Yield, vegetative growth, and fruit quality are highly correlated to soil moisture (Hardie and Considine, 1976; Van Rooyen, et al., 1980). Water use of cool-season grasses maintained as turf are estimated to be 2.4-7.5 mm per day (Beard, 1983). Water use of cool season grasses in a semi-arid climate under moderate management practices (irrigation and seasonal fertilization, with 4-6 mowings per season) are estimated to be 3.88-6.43 mm per day (Shearman, 1986). Few studies on the water use of cool-season grasses in the Willamette Valley under low management (nonirrigated with minimal number of mowings/year) have been conducted

(Vomocil, 1985; Wilson, 1985).

This study was conducted to measure the water use of four cool-season grass species under low management (nonirrigated, 3-4 mowings per year). Interests are in determining variable water use by the species to find grasses to compete with the vines and decrease excess growth. A neutron probe was used to measure moisture depletion of nonirrigated grass-plots. Measurements were made every 7-10 days during the growing season in 1986 and 1987. Evapotranspiration was calculated by the soil-water balance method.

MATERIALS AND METHODS

Bareground and six grass treatments were used in a randomized complete-block design to compare the water use of cool season grasses: Lolium perenne cv. 'Elka', L. perenne cv. 'Manhattan II', and L. perenne cv. 'Derby', Festuca arundinacea cv. 'Olympic', Agrostis tenuis cv. 'Highland', Dactylis glomerata cv. 'Pomar'. On 6 July 1985, 5-by-5 m plots were formed on a Chehalis silty clay-loam soil at the Lewis-Brown Horticultural Farm located 5 km east of Corvallis. Plots were plowed, disked, cultivated, and raked.

Holes were drilled 1.5 m deep in the center of each plot with a Giddings soil press using a 50-mm auger. Aluminum pipe with a 50-mm inner-diameter cut to 1.7 m was placed in each hole as the access tube for the neutron probe.

Grass was seeded on 16 July 1985, at 22.42 kg ha^{-1} for each species ($48.6 \text{ g seed plot}^{-1}$). Bareground plots were established using napropamid plus simazine at rates of 0.279 and 0.225 kg ha^{-1} , respectively. Plots were uniformly irrigated to keep them moist the first two weeks. Water was applied four times a day on days one and two, three times a day on day three, and twice a day on days four and five. During the second week, plots were irrigated once a day. Grass plots were sprayed with bromoxynil on 12 August 1985, at 1.123 l ha^{-1} . Plots were fertilized with Urea (46-0-0) and $2.80 \text{ kg N ha}^{-1}$ (15-15-15) on 28 August 1985, and 28 February 1986, respectively. A combination of 2,4D, mecoprop, and dicamba (0.306 ml m^2) was applied on 17 March 1986,

and 5 May 1987, for weed control. Diuron plus napropamid was applied to bareground plots on 17 March 1986, at 0.225 and 0.279 kg ha⁻¹ respectively. Sethoxydim was applied on 24 April 1986, for weed control. A 2% glyphosate solution was applied to bareground plots on 5 May 1987.

Soil samples for probe and site calibration at field capacity were taken from 12 randomly chosen plots at 10, 20, 30, 60, and 90 cm on 3 April 1986. Samples were oven dried for 24 hours at 40.5 °C, and bulk density and water content were determined. Soil samples for probe and site calibration at permanent wilting point were taken from 5 randomly chosen plots at 10, 30, and 55 cm. Additional samples at a depth of 10 cm were taken from 5 of the remaining plots. Water content and bulk density were determined as before. Calibration of the site and probe were performed according to the manufacturer's specifications.

Moisture readings at five depths (10, 20, 30, 60, and 90 cm) were taken every 7-10 days during the growing season--from 14 April to 28 July in 1986 and from 15 April to 27 August in 1987. Probe standard counts were converted to millimeters of water depletion in each zone by a computer program based on the number of recorded counts from hydrogen molecules in the soil, and the calibration curve for the site (Cuenca and Braunworth, 1985). Weather data for 12 hour periods were obtained from the Agriculture Engineering weather station at the Oregon State University Vegetable Crop Farm 4 km east of Corvallis, and 1 km north of the experimental site. Evapotranspiration was estimated by the soil water balance method. Core samples of field plots were taken on

17 February 1988. A Madera probe was used to take $6 \times 10^{-6} \text{ m}^3$ samples at 10 cm increments from 0-100 cm in each plot of 'Highland', 'Derby', 'Elka', 'Manhattan II', and 'Olympic'. Core samples were soaked in water until the soil was suspended. Samples were then strained through cheesecloth, resuspended, and strained through a 5 mm^2 mesh screen. Roots were removed from the screen, weighed, and dried. Dry weights were analyzed statically.

RESULTS AND DISCUSSION

Grass Seasonal Water Use:

Seasonal evapotranspiration and total depletion rates did not differ significantly among the cool-season grass species in this study (Table 4.1-4.2, and Figs. 4.1-4.2). Seasonal evaporation rates and total depletion rates were higher in 1986 than in 1987, with differences between years being a function of seasonal variation and possible low fertility in 1987. Fertilizer was applied only once during the 2 year experimental period. Low fertility is shown to reduce grass regrowth in the fall and spring, reduce transpiration and growth, and reduce wear tolerance (Garwood and Williams, 1966; Feldhake, et al., 1980; Biran, et al, 1981). Low fertility is also linked with water deficiency because water soluble nutrients, such as nitrogen, are taken up via soil solution. Soil water deficiencies can induce nutrient deficiencies by limiting the medium through which these nutrients are absorbed (Mengel and Kirkby, 1982). Differences between seasonal evapotranspiration rates of all grass treatments were not significantly greater than bareground in 1986 or 1987. Only 'Highland' bentgrass had significantly greater seasonal evapotranspiration rates than bareground plots in 1986, with 'Highland' bentgrass and 'Derby' perennial ryegrass plots having significantly greater seasonal evapotranspiration than bareground plots in 1987. Total depletion of 'Highland' bentgrass, 'Olympic' tall fescue, and 'Derby' perennial ryegrass was significantly greater than bareground plots in 1986, while differences in total depletion among all treatments was not significant in 1987. Variability was high among replica-

tions in each treatment.

Water use of grass species is a function of several climatic factors, and therefore is highly dependent on the climate of the region where the grass is grown (Penman, 1949). When soil moisture is adequate, radiant energy is the governing factor in water use. Under water stress conditions, evapotranspiration is the governing factor of water use by plants (Tovey, et al., 1969). Evapotranspiration consists of evaporation from the soil surface combined with transpiration from plants (Salisbury and Ross, 1978). It accounts for total water loss from the plant-soil continuum excepting run-off and deep percolation.

Studies on evapotranspiration of cool-season grass species under moderate management shows evapotranspiration to range from 3.88-6.43 mm per day (Shearman, 1986), and from 2.40-7.88 mm per day (Beard, 1983). Water use by grass is influenced by species and cultivar (Welton and Wilson, 1931; Burton, et al., 1957), but these differences were not significant under the low maintenance conditions of this experiment. Few water use studies of cool-season grass species under low maintenance conditions have been performed in the Pacific Northwest (Vomocil, 1985; Wilson, 1985), but water use of perennial ryegrass (L. perenne) grown under natural conditions in midwestern U.S. is 50.8 mm from April-June (Garwood and Williams, 1967). Similar studies show that from May-September, orchardgrass uses 78.7 mm, Chewings fescue uses 106.68 mm, Sheep fescue uses 114.5 mm, and Kentucky bluegrass uses 142.24 mm of water. (Garwood and Williams, 1967). These values are generally lower than the values under low mainte-

nance conditions in the Pacific northwest.

Depletion in soil layers under grass

Total depletion of water in each layer for 1986 and 1987 is presented in Table 4.3 and 4.4, and total depletion by each layer for 'Derby' perennial ryegrass is presented in Fig. 4.3 for 1986, and Fig. 4.4 for 1987. Depletion in all layers was not significantly different between grass species in either season. Depletion of grass plots in 1986 was significantly greater than bareground plots in the 0-15, 35-75, and 75-105 cm layers. In 1987, only 'Derby' and 'Elka' perennial ryegrass and 'Olympic' tall fescue had significantly greater depletion than bareground in the 0-15 cm layer. This is most likely due to these species having greater root density in this layer. Depletion values were not significantly different than bareground in the 15-25 cm layer, while all grass species had significantly greater depletion in the 25-35 and 35-75 cm layers. Depletion values were not significantly different in the 75-105 cm layer. Water use of the grasses in the 0-15 cm zone was 3 times greater than water depletion in the 15-25, 25-35, and 35-75 cm zones. Water depletion in these lower layers was uniform, but decreased in the 75-105 cm zone. Competition for water with grapevines would be greatest in the 0-15 cm soil layer.

Water competition from grass cover crops has been implicated as reducing vegetative growth, plant vigor, and fruit quality and yield (Veihmeyer and Hendrickson, 1950; Kobayashi, et al., 1963; Hardie and Considine, 1976; Haynes, 1980; Van Rooyen, et al.,

1980; Morlat, 1981; Morlat, et al., 1981; Van Huyssteen, et al., 1983; Perret and Koblet, 1985; Murisier and Beuret, 1985; Becker, 1986; Muller, 1986). Water competition from grass is greatest in the upper soil layers where rooting of the grass is dense, and water use is greatest (Morlat, 1981). Roots of crop plants root deeper in search of available moisture (Morlat, 1981; Morlat, et al., 1981). Studies in vineyards in the Pacific Northwest have illustrated a decreased rooting of grapevines in the upper soil horizon in the presence of a ryegrass cover crop (Lombard, et al., 1988).

Evapotranspiration profile by month

Average monthly evapotranspiration rates for the 1986 and 1987 growing seasons are presented in Tables 4.5 and 4.6. Average monthly evapotranspiration for 'Pomar' orchardgrass in 1986 and 1987 is presented in Fig. 4.5. Evapotranspiration differences between grass species was not significant in July of 1986. In April 'Elka' perennial ryegrass evapotranspiration was significantly greater than bareground, in May 'Elka' perennial ryegrass and 'Olympic' tall fescue had significantly greater evapotranspiration over bareground. In June all grass treatments had greater evapotranspiration than bareground and 'Olympic' tall fescue had significantly greater evapotranspiration than 'Elka' perennial ryegrass and 'Pomar' orchardgrass. This difference among species is a result of tall fescue being a deeper rooting grass. In 1986 the evapotranspiration rates of all grass treatments peaked in May. Changes in evapotranspiration rates of orchardgrass and bentgrass were gradual, while evapotranspiration

rates for all ryegrass plots and tall fescue decreased markedly in June and July.

Evapotranspiration differences among the grass species was not significant in any month in the 1987 growing season. As in 1986, the 1987 evapotranspiration values peaked in the early part of the growing season (May), which was a function of adequate soil moisture. Evapotranspiration rates were uniform for all species in April and May, but in June, evapotranspiration rates for all grass species decreased about 50 %. In August 1987 bareground plots had significantly greater evaporation than all grass treatments. Periodic heavy rainfall in August coupled with warm temperatures resulted in high evaporation from the surface of bareground plots. The grass plots held moisture in the soil with the dormant grass serving as a cover to reduce evaporation. Transpiration by the grasses was minimal due their dormant condition. During summer months, water use by the grasses is reduced due to dormancy. Although species such as D. glomerata and F. arundinacea do not go dormant under water stress conditions, results from this study show their water use to not be significantly higher than dormant grasses. This results in minimal competition from grass during the dry summer months if the crop is nonirrigated. Studies in the Willamette Valley vineyards shows water use does not differ significantly between bareground and cover-cropped rows (Vomocil, 1985). Loss in transpiration by cover cropped rows is compensated by reduced evaporation (Vomocil, 1985).

Growth of grass is reduced under drought conditions (Penman,

1949; Juska and Hansen, 1966). The drought tolerance of grass species differs (Gaskin, 1966; Beard, 1983), with the continuum, from high to low, being tall fescue, perennial ryegrass, and bentgrass (Beard, 1983). Drought stress reduces evapotranspiration rates (Feldhake, et al., 1983) and regeneration rates. Ryegrass began to go dormant before bentgrass even though bentgrass is considered to have a lower drought tolerance than ryegrass. Tall fescue and orchardgrass plots remained green throughout the summer season, but evapotranspiration rates were not significantly greater than plots which appeared to be dormant. Even in plots which appeared to be completely dormant, some evapotranspiration was taking place. These values are minimal and could represent evaporation from the soil.

Rooting of grasses

Root density data (Table 4.7) present trends in rooting density of each of the species sampled. Root density data from core samples of grass species were similar to trends shown in other studies (Stuckey, 1941). 'Olympic' tall fescue had greater root density at the lower depths. Ryegrass rooted as deep as tall fescue, but density values were near zero in the 60-100 cm layers. The greatest root density for ryegrass was in the 0-60 cm layers. 'Highland' bentgrass had the lowest root density in the 0-20 cm layers but root density increased in the 20-70 cm layers, while root density was low in the 80-100 cm layers. These results are similar to those of Partridge (1941) who found greater root weights in the upper soil layers.

Both ryegass and bentgrass have annual root systems (Stuckey, 1941). With annual root systems, roots are regenerated in the fall and spring each year. Regeneration is greatest in the spring (Stuckey, 1941; Troughton, 1957). Tall fescue has a coarse perennial root system (Troughton, 1957). The maximum production of new roots occurs during the first year of growth. These roots remain functional for more than one year. Because core sampling was performed in late February of 1987, spring root regeneration of the grass species with annual root systems may not have occurred. This may account for the low root density of ryegrass and bentgrass roots relative to tall fescue in the upper soil layers (Stuckey, 1941; Troughton, 1957; Beard, 1983). Both ryegrass and bentgrass have finer roots than tall fescue, therefore weight measurements may be misleading.

Water depletion per layer was correlated to root density for all grass plots sampled except 'Highland' bentgrass (Table 4.8). A low correlation for bentgrass is most likely a result of the time lag between water measurements and root samples, and because of its annual root system. Root density values in April-August may not be accurately represented by root density the following February in grass species with annual root systems. 'Derby' and 'Manhattan II' perennial ryegrass, which have annual root systems, also had lower values than 'Elka' dwarf perennial ryegrass and 'Olympic' tall fescue. Other factors contributing to the low values may be that the presence of roots in any one layer is no indication of activity and that rooting is highly variable under field conditions.

CONCLUSIONS

Seasonal evapotranspiration and total depletion of soil water were not significantly different among the cool season grass species used in this study. Evapotranspiration values under low maintenance conditions in the Willamette Valley, Oregon, are lower than under moderate maintenance conditions (Beard, 1983). In some cases grass evapotranspiration was not significantly greater than bareground, with evaporation in the late summer months being significantly higher on bareground plots. Evapotranspiration peaked in late spring, then decreased because of dormancy of the grasses. Results of this study show competition for soil water from grass cover crops can be minimal due to the grasses going dormant. The affects of competition for soil water is dependent on the drought tolerance of the crop being grown, the water requirements of the crop, and the percentage of ground covered by the cover crop (Marlett, 1958). Benefits of grass cover crops can be the reduction of soil erosion, aeration of soil for better water penetration, reduced soil compaction, and possibly a reduction in evaporation of water from the soil surface in warm weather.

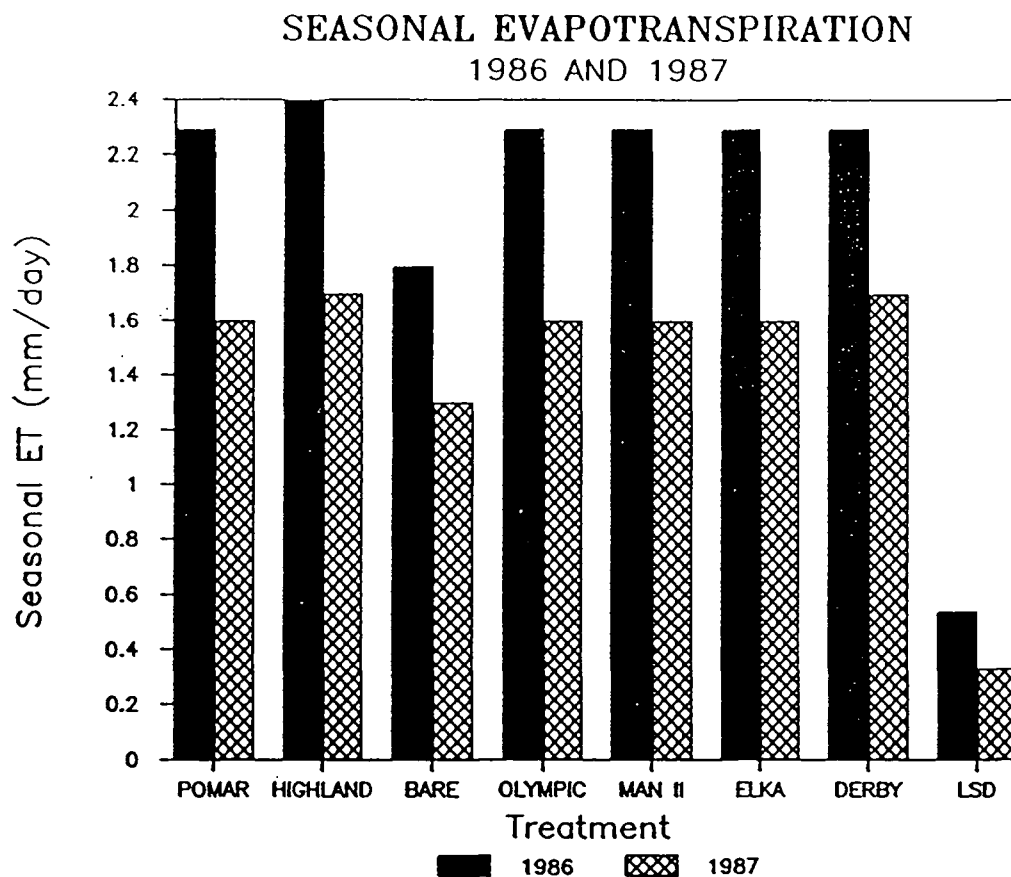


Figure 4.1 Seasonal evapotranspiration of six grasses and bareground on Chehalis silty clay loam soil in Corvallis, Oregon, 1986 and 1987.

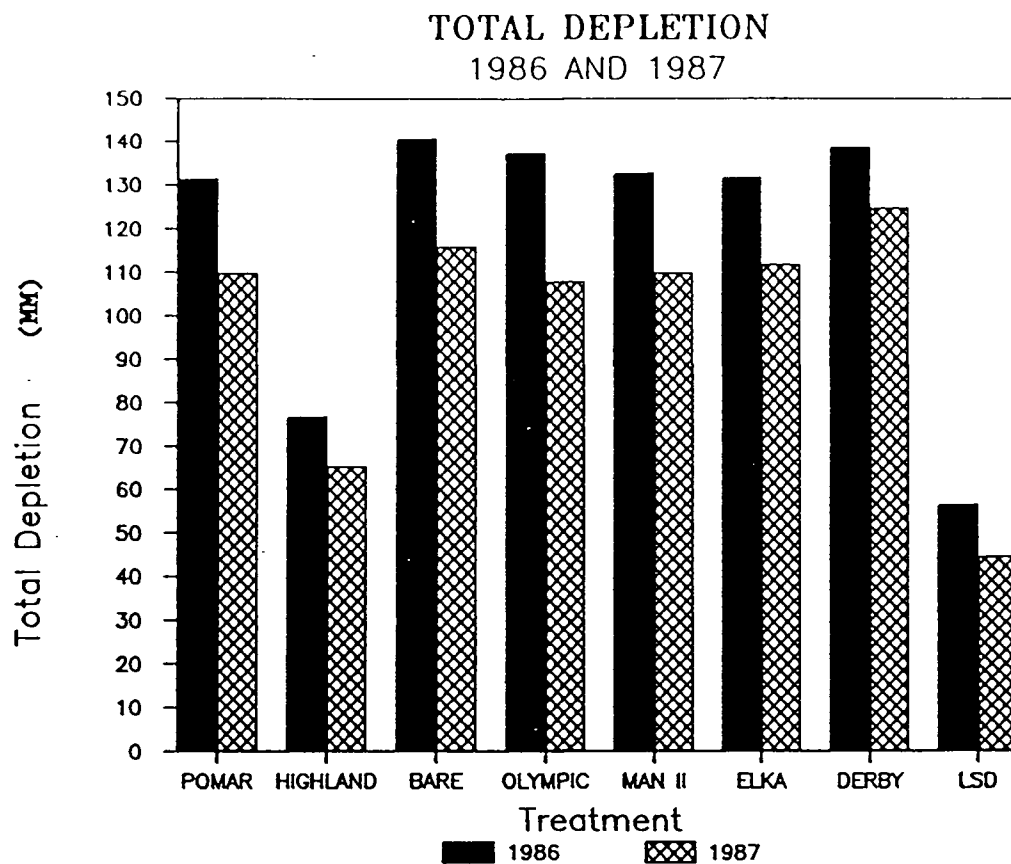


Figure 4.2. Total depletion of water under six grasses and bareground on Chehalis silty clay loam soil in Corvallis, Oregon, 1986 and 1987.

Figure 4.3. Total depletion of water in each soil layer under 'Derby' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.

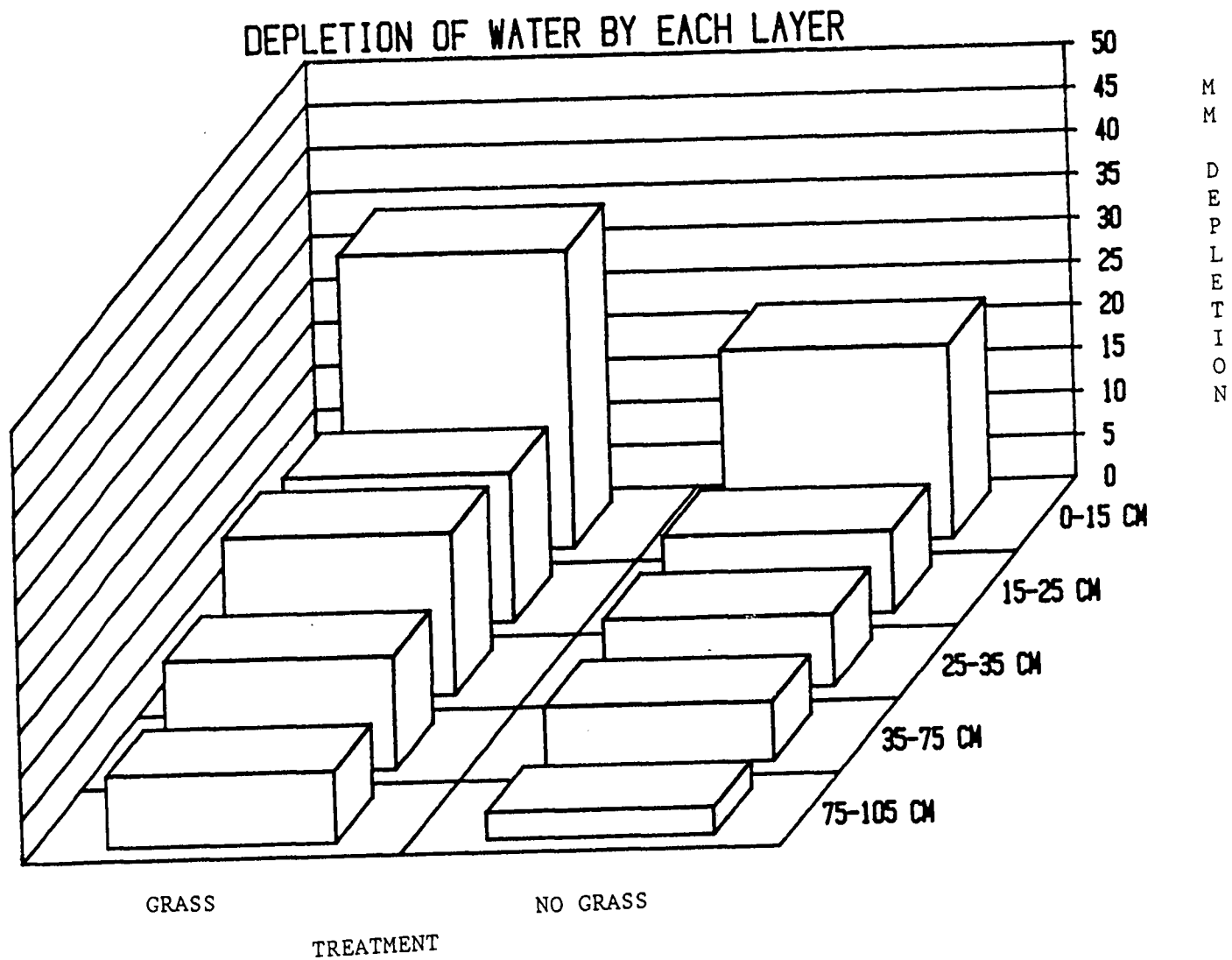
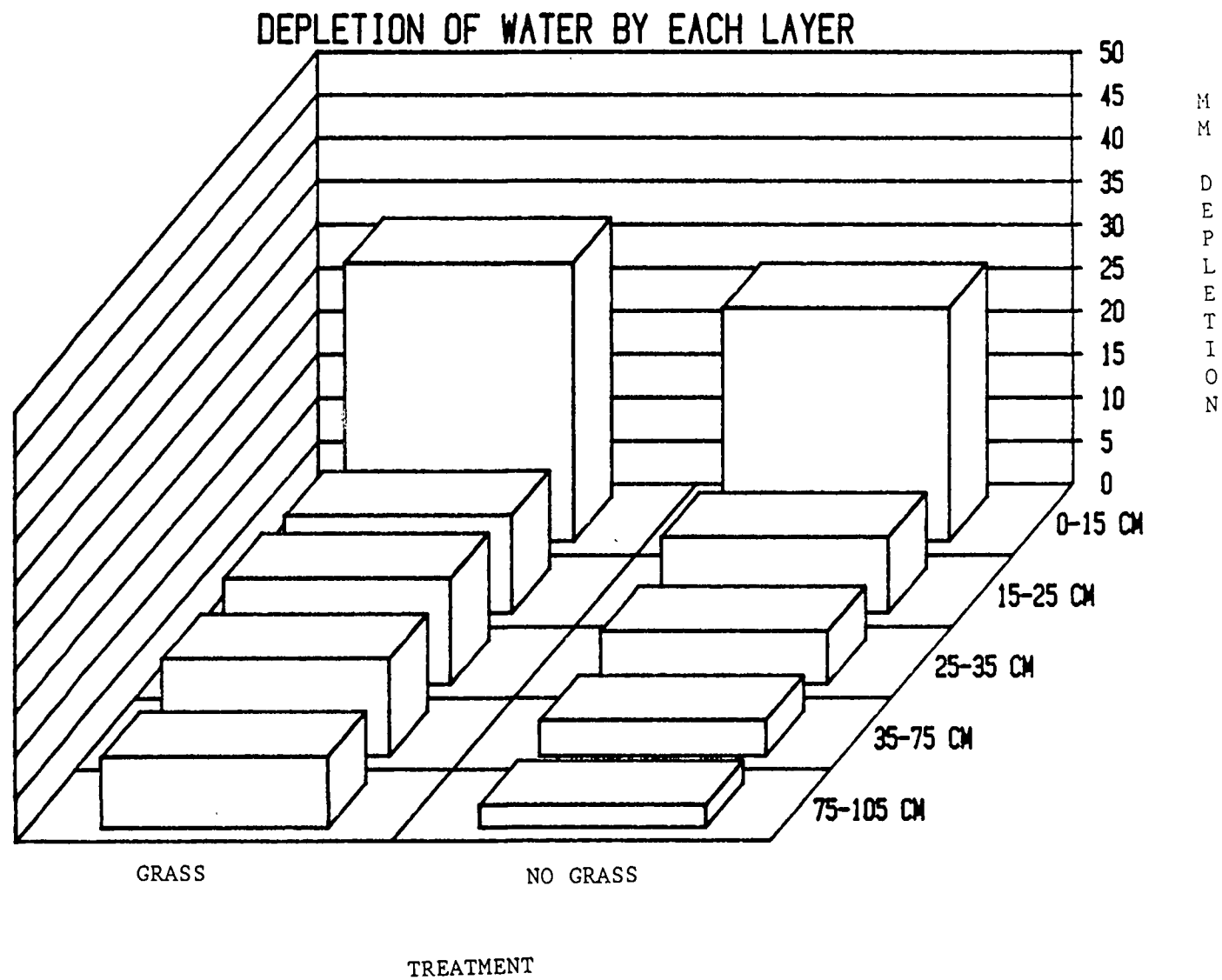


Figure 4.4. Total depletion of water in each soil layer under 'Derby' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



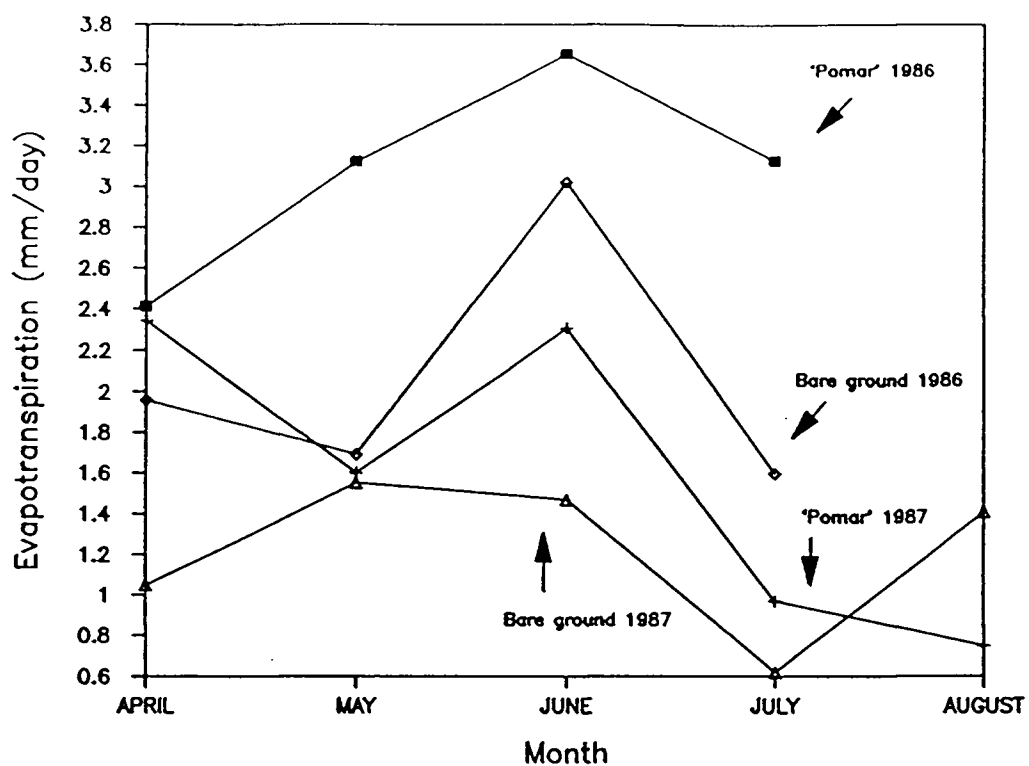


Figure 4.5. Average monthly evapotranspiration of 'Pomar' orchardgrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986 and 1987.

Table 4.1. Seasonal evapotranspiration of grass plots and bareground, Corvallis, Oregon, during the season of 1986 and 1987.

Grass Treatment	Evapotranspiration (mm day ⁻¹)	
	14 April-28 July 1986	15 April-27 August 1987
'Pomar' perennial ryegrass	2.3	1.6
Bareground	1.8	1.3
'Highland' bentgrass	2.4	1.7
'Olympic' tall fescue	2.3	1.6
'Manhattan II' perennial ryegrass	2.3	1.6
'Elka' perennial ryegrass	2.3	1.6
'Derby' perennial ryegrass	2.3	1.7
Standard Error of Mean	0.18	0.11
LSD (.05)	0.54	0.33

Table 4.2. Total depletion of soil water by grass plots and bareground in the 0-100 cm soil layers, Corvallis, Oregon during 1986 and 1987.

Grass Treatment	Water Depletion (mm day ⁻¹)	
	14 April-28 July 1986	15 April-27 August 1987
'Pomar' Orchardgrass	131.7	110.0
Bareground	77.0	65.5
'Highland' bentgrass	141.0	116.7
'Olympic' tall fescue	137.7	108.5
'Manhattan II' perennial ryegrass	133.0	109.7
'Elka' perennial ryegrass	132.2	112.5
'Derby' perennial ryegrass	139.5	125.5
Standard Error of Mean	19.3	14.6
LSD (0.05)	56.7	77.2

Table 4.3. Depletion of soil water at 5 depths under six grass species and bareground, Corvallis, Oregon, 1986.

Grass Treatment	water depletion (mm)				
	0-15cm	15-25cm	25-35cm	35-75cm	75-105cm
'Pomar' orchardgrass	33.7	13.0	13.2	13.0	6.6
Bareground	22.5	9.2	8.5	6.8	3.2
'Highland' bentgrass	32.5	11.7	14.0	13.3	9.9
'Olympic' tall fescue	37.0	14.0	14.7	12.8	7.0
'Man II' p. ryegrass	36.0	13.5	14.5	10.4	9.2
'Elka' p. ryegrass	34.7	13.7	13.7	12.8	4.9
'Derby' p. ryegrass	34.5	17.0	19.0	13.2	8.3
Standard Error of Mean	2.56	2.27	2.34	1.77	3.14
LSD (0.05)	7.53	6.68	6.89	3.37	9.22

Table 4.4. Depletion of soil water at 5 depths under six grass species, Corvallis, Oregon, 1987.

Grass Treatment	water depletion (mm)				
	0-15cm	15-25cm	25-35cm	35-75cm	75-105cm
'Pomar' orchardgrass	30.2	10.5	10.7	11.1	4.7
Bareground	27.2	9.0	6.2	4.1	2.5
'Highland' bentgrass	30.2	9.5	11.0	10.0	8.7
'Olympic' tall fescue	32.5	10.7	10.5	9.1	6.1
'Man II' p. ryegrass	31.7	11.0	12.2	8.6	6.7
'Elka' p. ryegrass	34.7	11.5	11.7	9.9	4.9
'Derby' p. ryegrass	32.2	11.5	11.2	12.5	8.2
Standard Error of Mean	1.52	1.01	1.20	1.47	2.77
LSD (0.05)	4.46	2.98	3.53	4.34	8.15

Table 4.5. Mean monthly evapotranspiration of six grass species and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1986.

Grass Treatment	mean monthly evapotranspiration (mm day ⁻¹)			
	April	May	June	July
'Pomar' orchardgrass	2.4	3.6	2.3	2.3
Bareground	1.9	3.0	1.0	1.5
'Highland' bentgrass	2.4	3.8	2.7	1.8
'Olympic' tall fescue	1.9	4.4	3.7	1.3
'Manhattan II' p. ryegrass	2.8	4.1	2.7	1.5
'Elka' p. ryegrass	2.9	4.3	2.5	1.0
'Derby' p. ryegrass	2.5	3.8	2.9	1.8
Standard Error of Mean	0.6	0.6	0.6	0.7
LSD (0.05)	1.0	0.9	1.0	1.1

Table 4.6. Mean monthly evapotranspiration of six grass species and bareground in Corvallis, Oregon, 1987.

Grass Treatment	mean monthly evapotranspiration (mm day ⁻¹)				
	April	May	June	July	August
'Pomar' orchardgrass	3.2	3.1	1.6	1.0	0.7
Bareground	1.7	1.6	1.5	0.6	1.4
'Highland' bentgrass	3.2	3.3	1.7	1.0	0.4
'Olympic' tall fescue	3.1	3.7	1.3	1.0	0.2
'Manhattan II' p.ryegrass	3.1	3.1	1.7	0.9	0.4
'Elka' perennial ryegrass	2.9	3.4	1.6	0.8	0.6
'Derby' perennial ryegrass	3.1	3.4	1.7	0.9	0.6
Standard Error of Mean	0.5	1.0	0.6	0.4	0.4
LSD (0.05)	0.8	1.5	0.9	0.6	0.6

Table 4.7 Root density (g/cm³) of 'Highland' bentgrass, 'Derby' p. ryegrass, 'Elka' p. ryegrass, 'Manhattan II' p. ryegrass, and 'Olympic' tall fescue grass plots at 10 cm increments in Chehalis silty clay-loam soil, Corvallis, Oregon, 1988.

Treatment	Depth (cm):									
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
	root density g.cm ⁻³									
Highland	9	13	21	22	4	35	20	6	5.00	0.080
Derby	30	26	23	14	6	48	5	1	0.40	0.004
Elka	45	30	20	14	7	10	4	2	0.07	0.005
Man II	39	40	25	18	17	13	5	4	0.02	0.009
Olympic	47	31	15	11	14	19	31	16	17.00	0.071
St. Error	5	5	4	3	4	4	5	1	1	0.02
LSD (0.05)	15	15	12	9	14	12	14	4	4	0.05

Table 4.8. R^2 values and correlation coefficients for root density and water depletion by depth for 5 grasses, February, 1988.

Grass Treatment	Correlation of root density and depletion by depth	
	r	R^2
'Highland' bentgrass	-0.15	0.02
'Derby' p. ryegrass	0.59	0.35
'Elka' p. ryegrass	0.84	0.71
'Man II' p. ryegrass	0.62	0.38
'Olympic' tall fescue	0.71	0.51
Significance at 0.05	0.67	

n=8

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CONCLUSIONS

Cool season grass species used as cover crops in vineyards in the Willamette Valley, Oregon are potentially allelopathic, and can inhibit the growth and development of uncultured grapevine cuttings when established prior to the vines or before young vines have become well-established. In vineyards in the Willamette Valley vines are allowed to become well-established before grass cover crops are seeded, thus the relative importance of the potential allelopathy of these grasses under field conditions is minimal. These cool season grasses also compete with the vines for soil water, but under low maintenance conditions the competition is reduced by the grasses going dormant during dry summer months. In late summer months, evaporation from bareground can exceed evapotranspiration from dormant grasses. Water use by the grasses was greatest in the 0-15 cm soil layer where grasses are the most densely rooted and where competition for water would be the most pronounced. Differences in the water use among the cool season grass species studied in this experiment may be greater in the fall months when the grasses are greening up due to fall rains.

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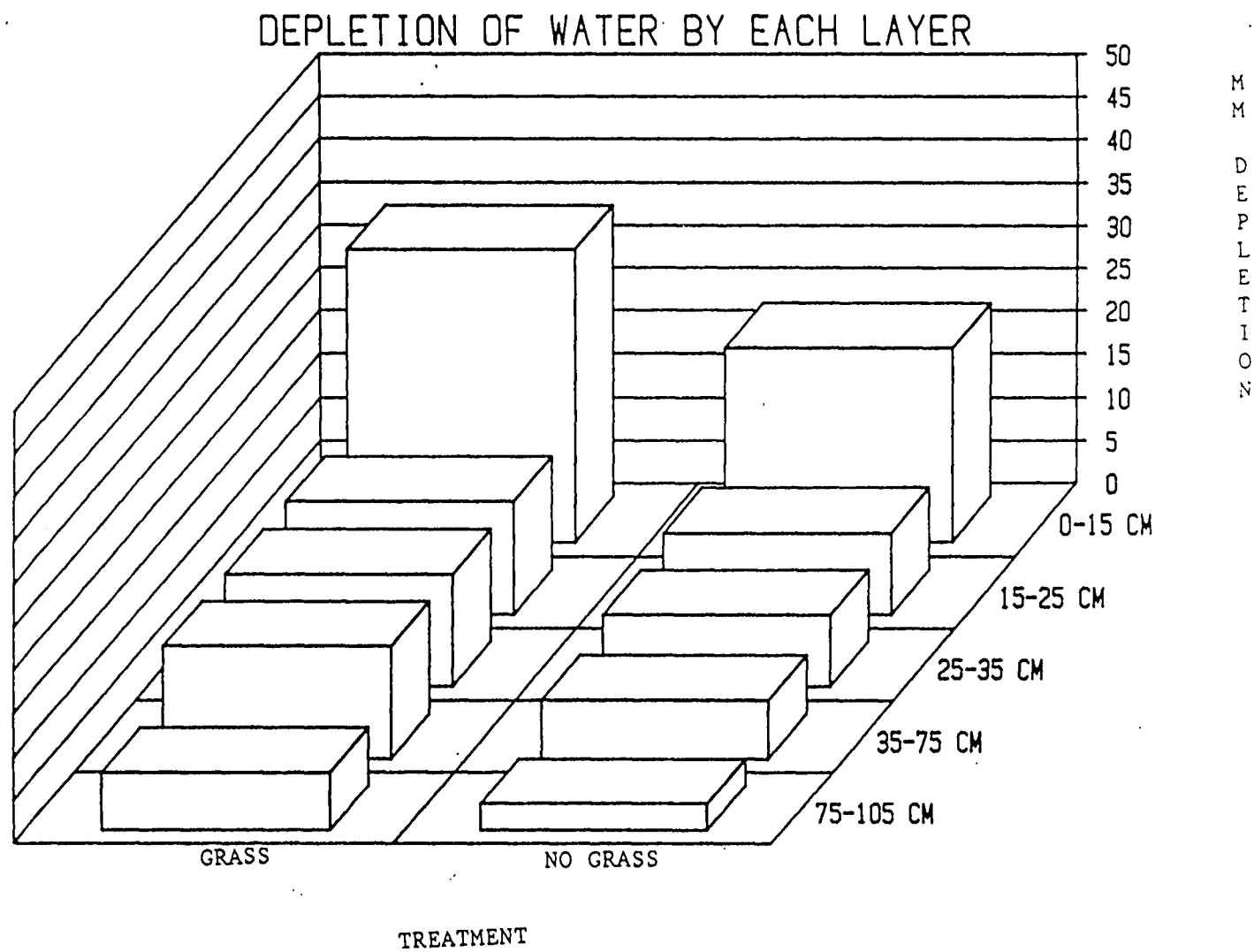
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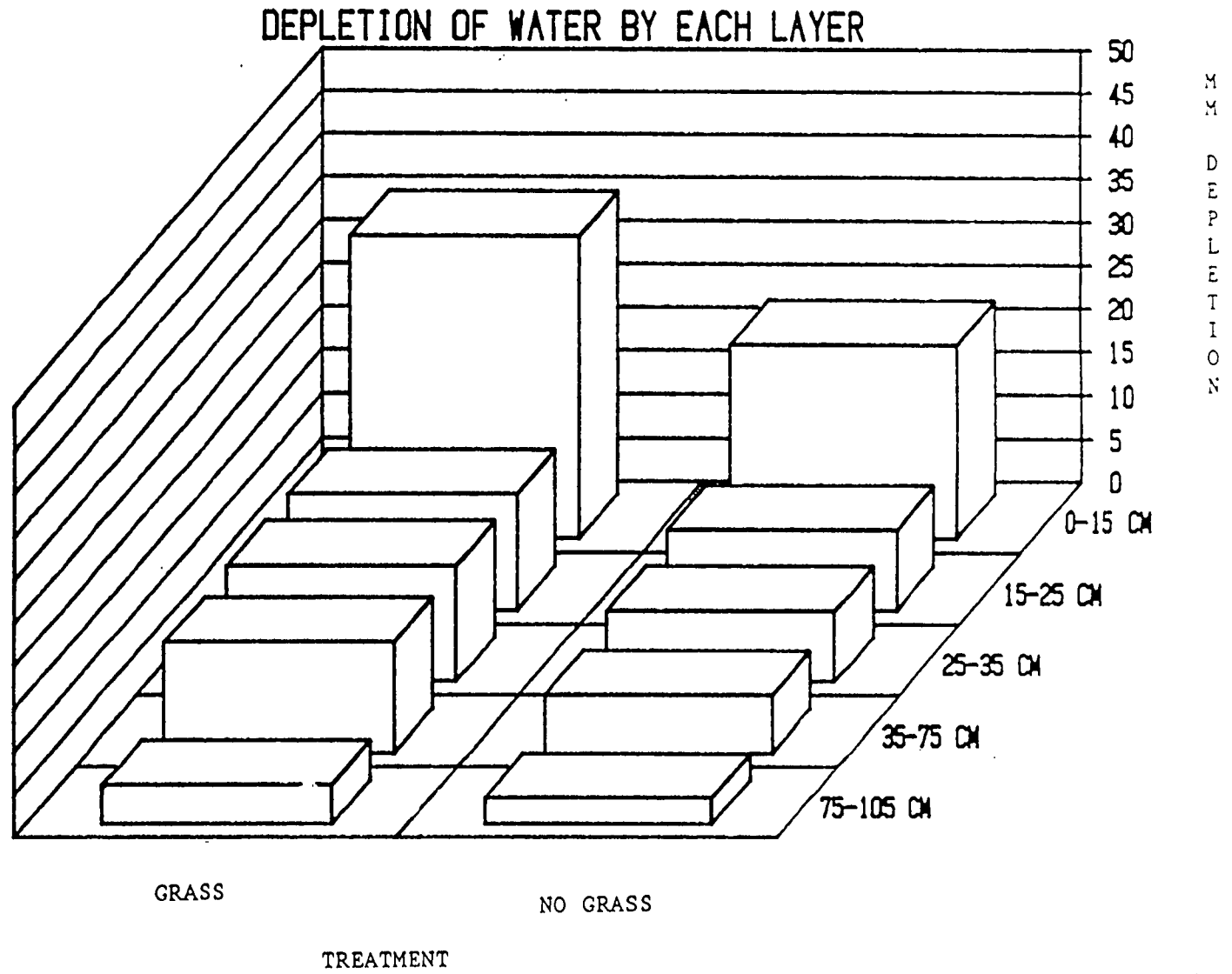
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APPENDICES

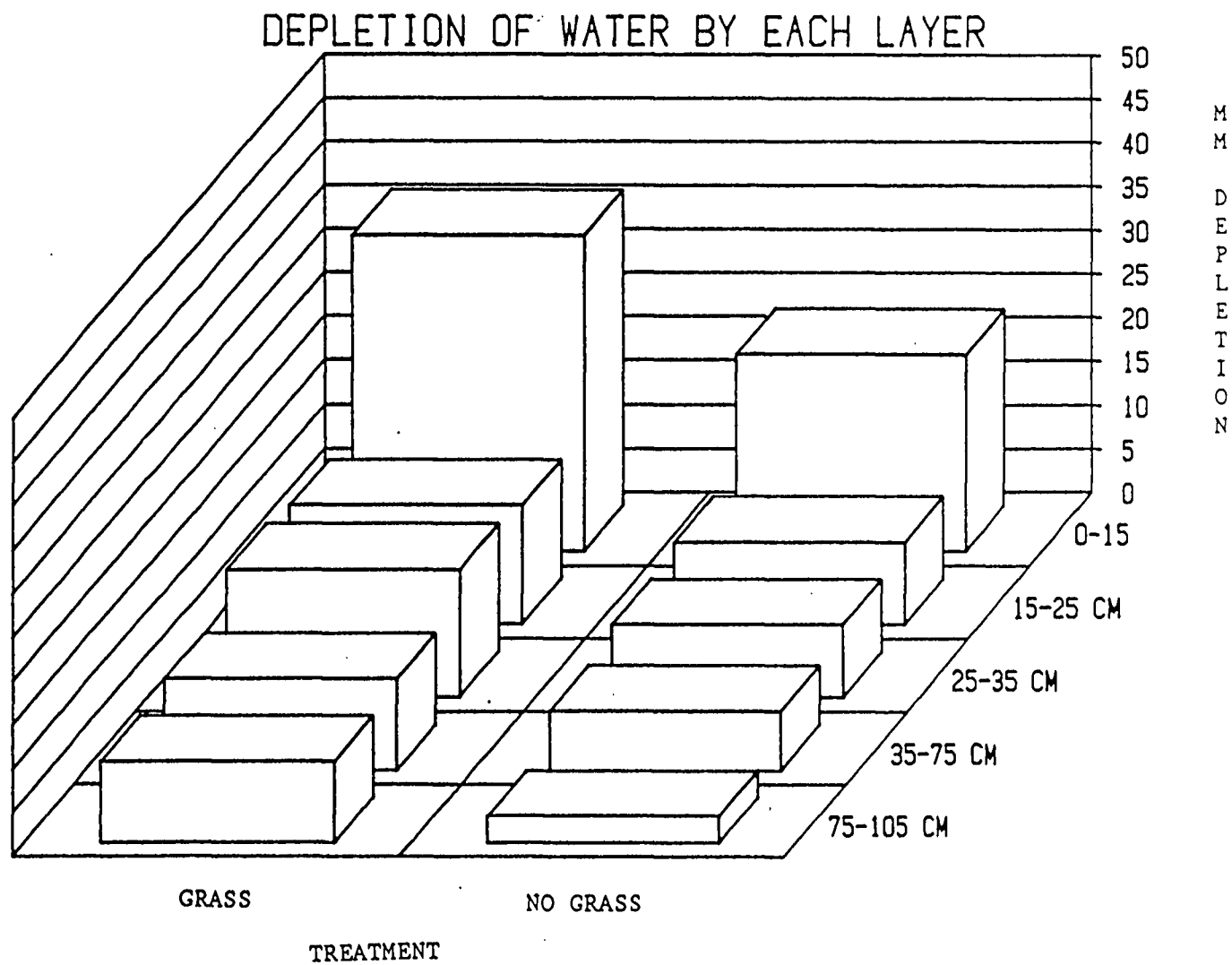
Appendix 1. Total depletion of water in each soil layer under 'Pommar' orchardgrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



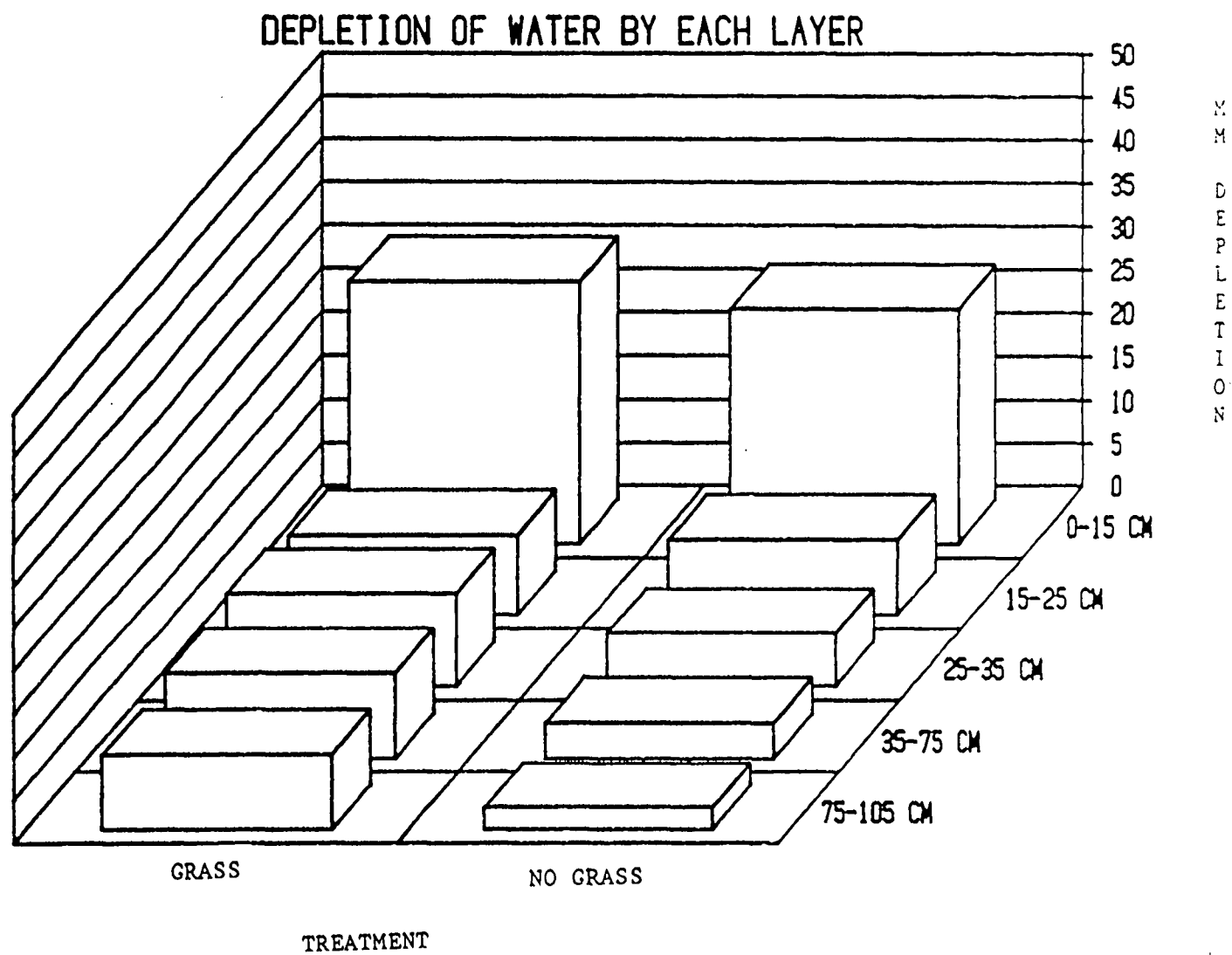
Appendix 2. Total depletion of water in each soil layer under 'Pomar' orchardgrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



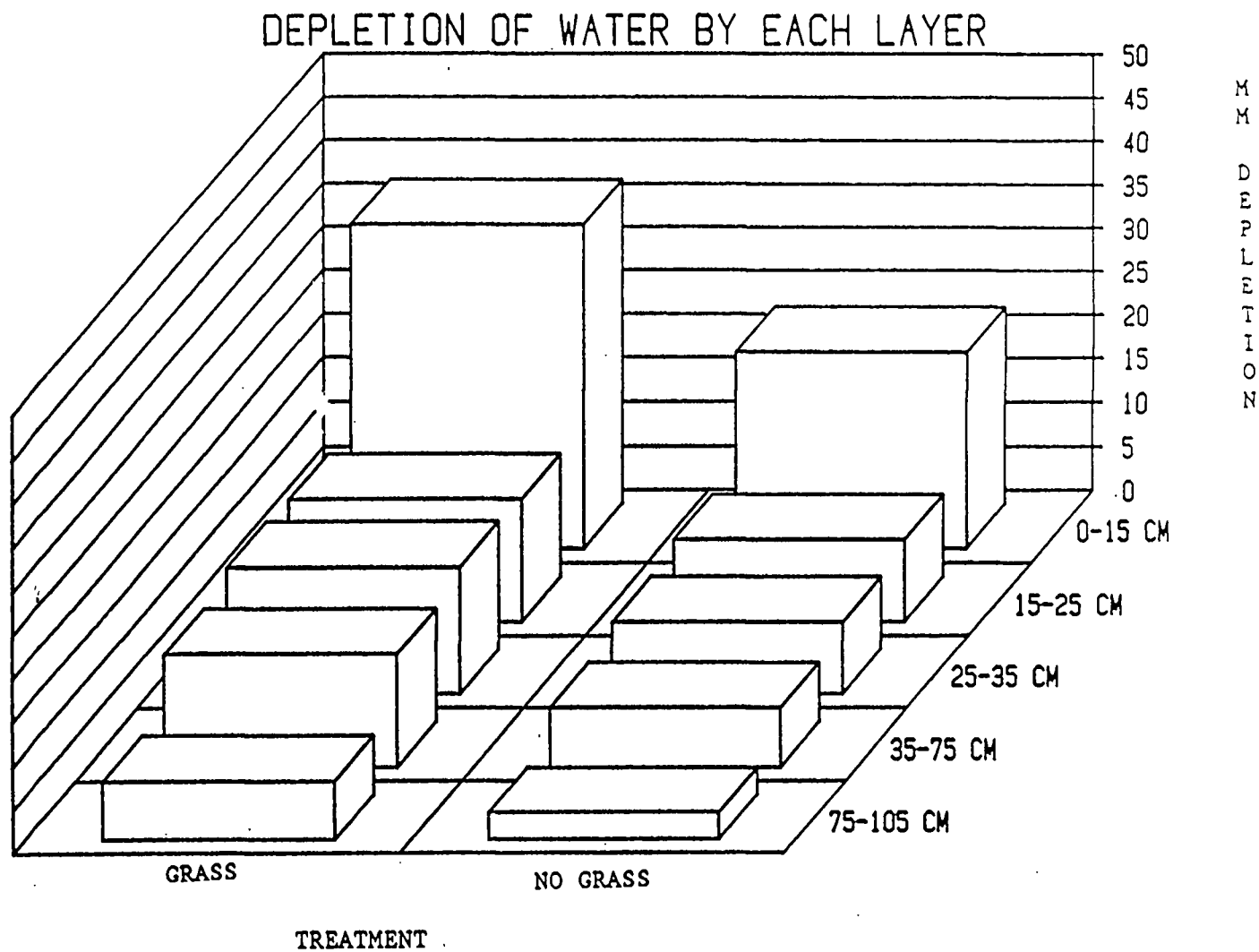
Appendix 3. Total depletion of water in each soil layer under 'Highland' bentgrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



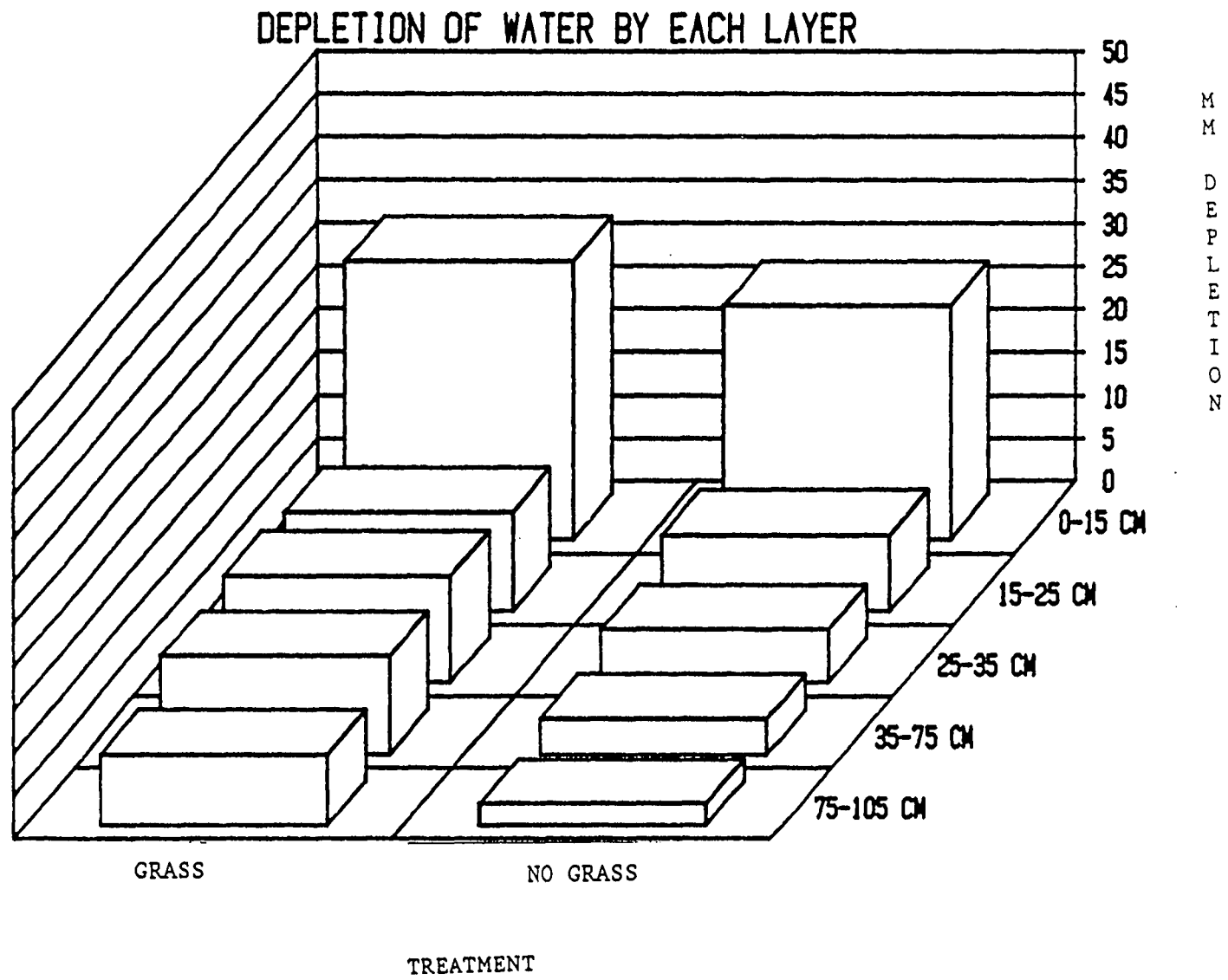
Appendix 4. Total depletion of water in each soil layer under 'Highland' bentgrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



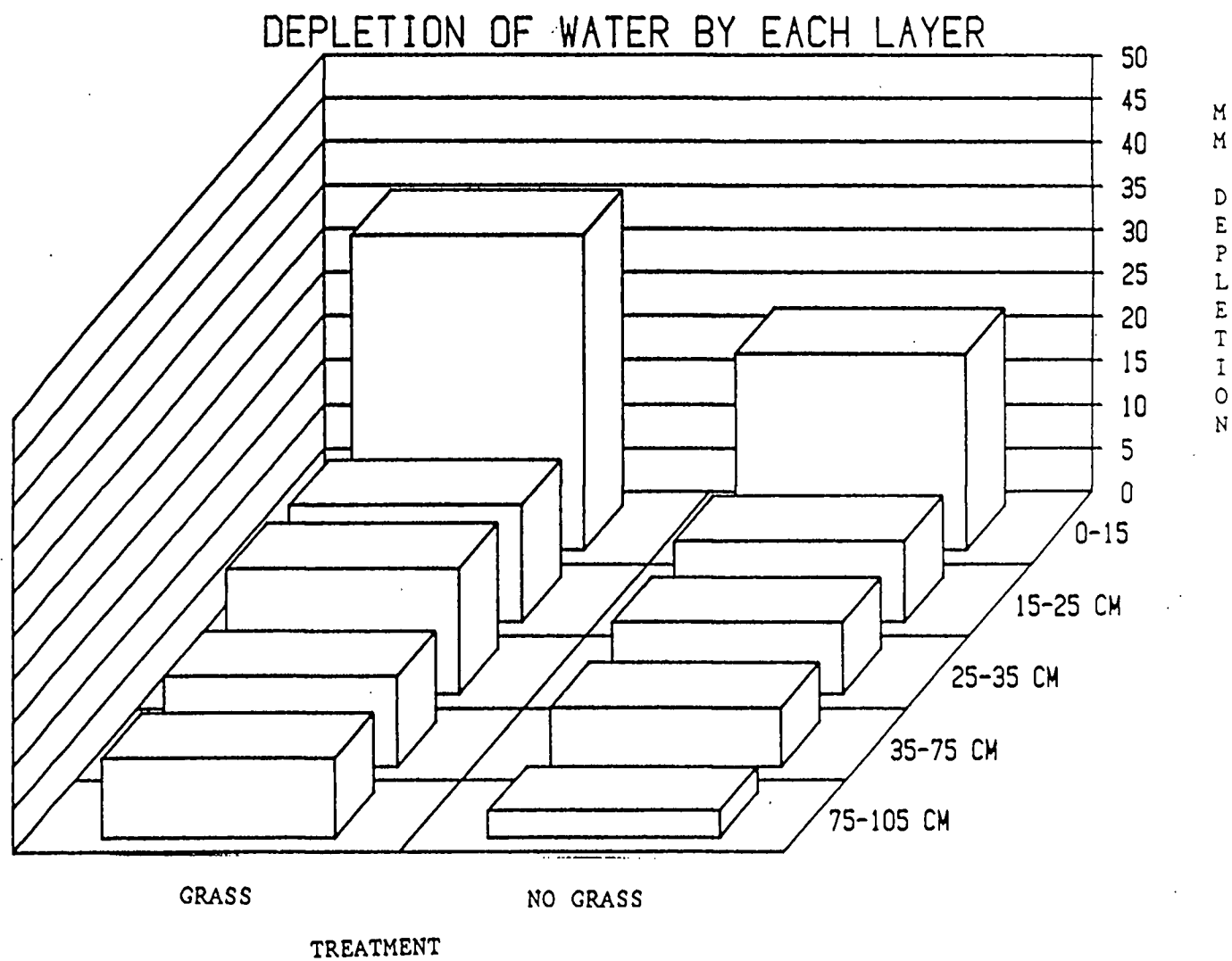
Appendix 5. Total depletion of water in each soil layer under 'Olympic' tall fescue on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



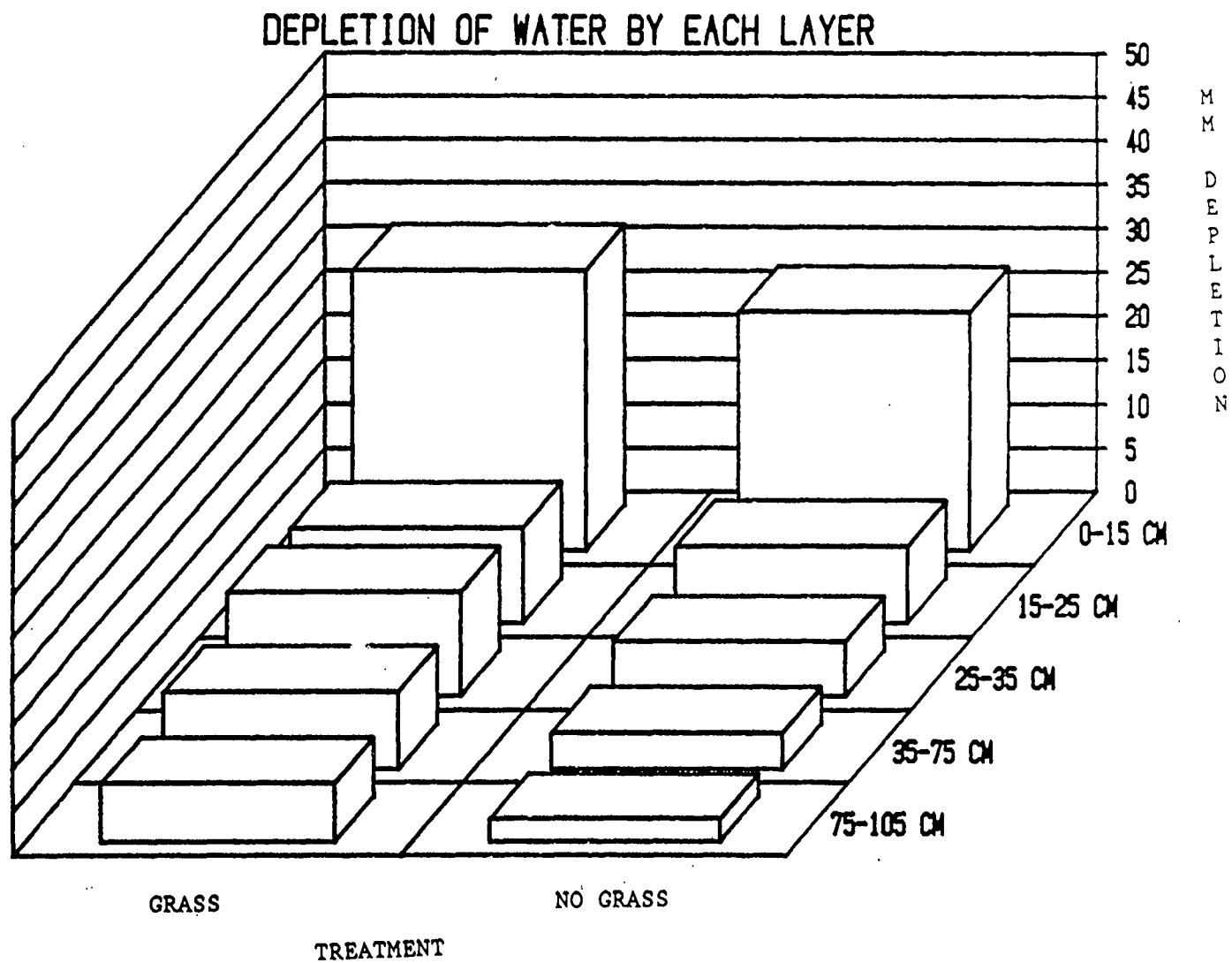
Appendix 6. Total depletion of water in each soil layer under 'Olympic' tall fescue on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



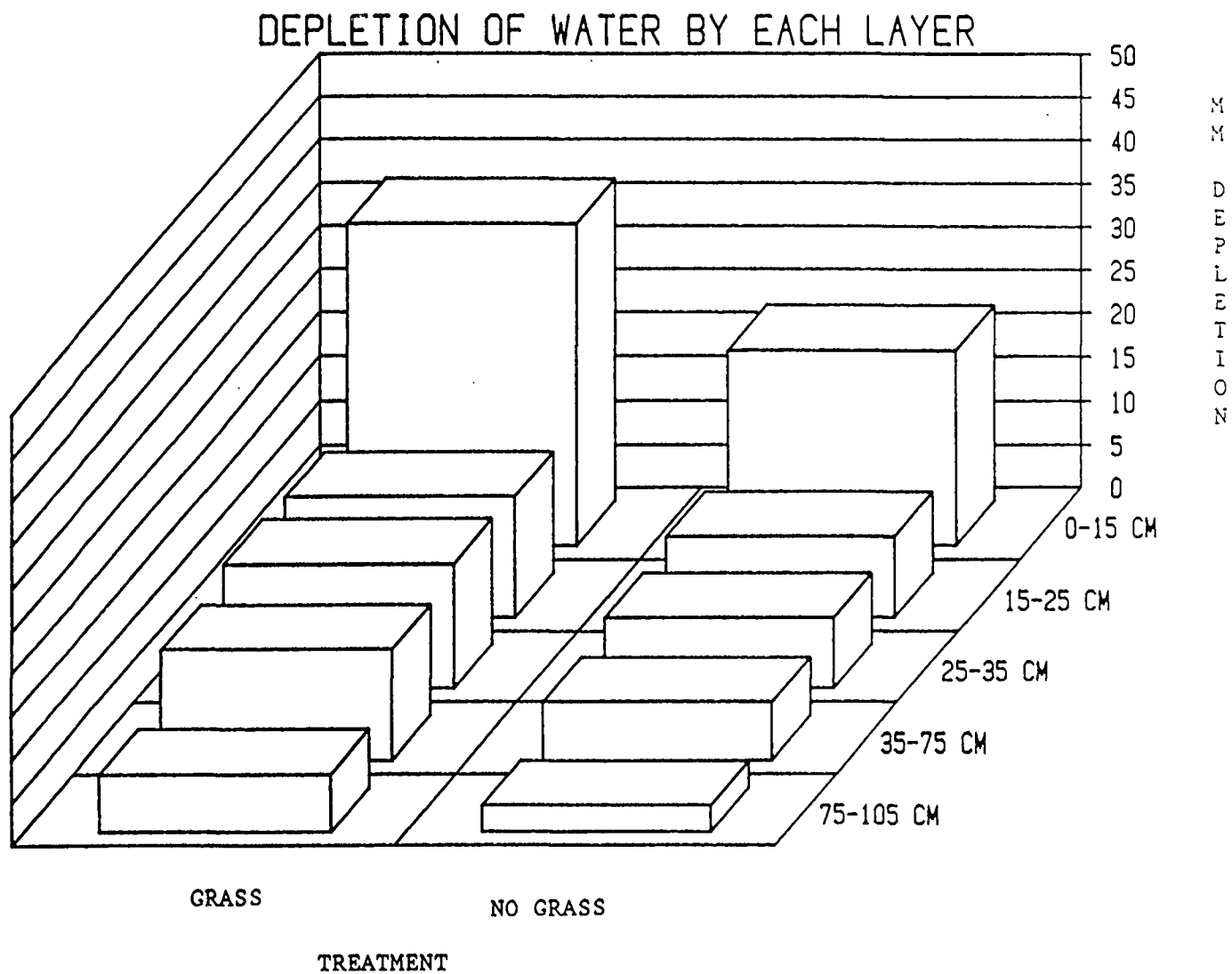
Appendix 7. Total depletion of water in each soil layer under 'Manhattan II' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



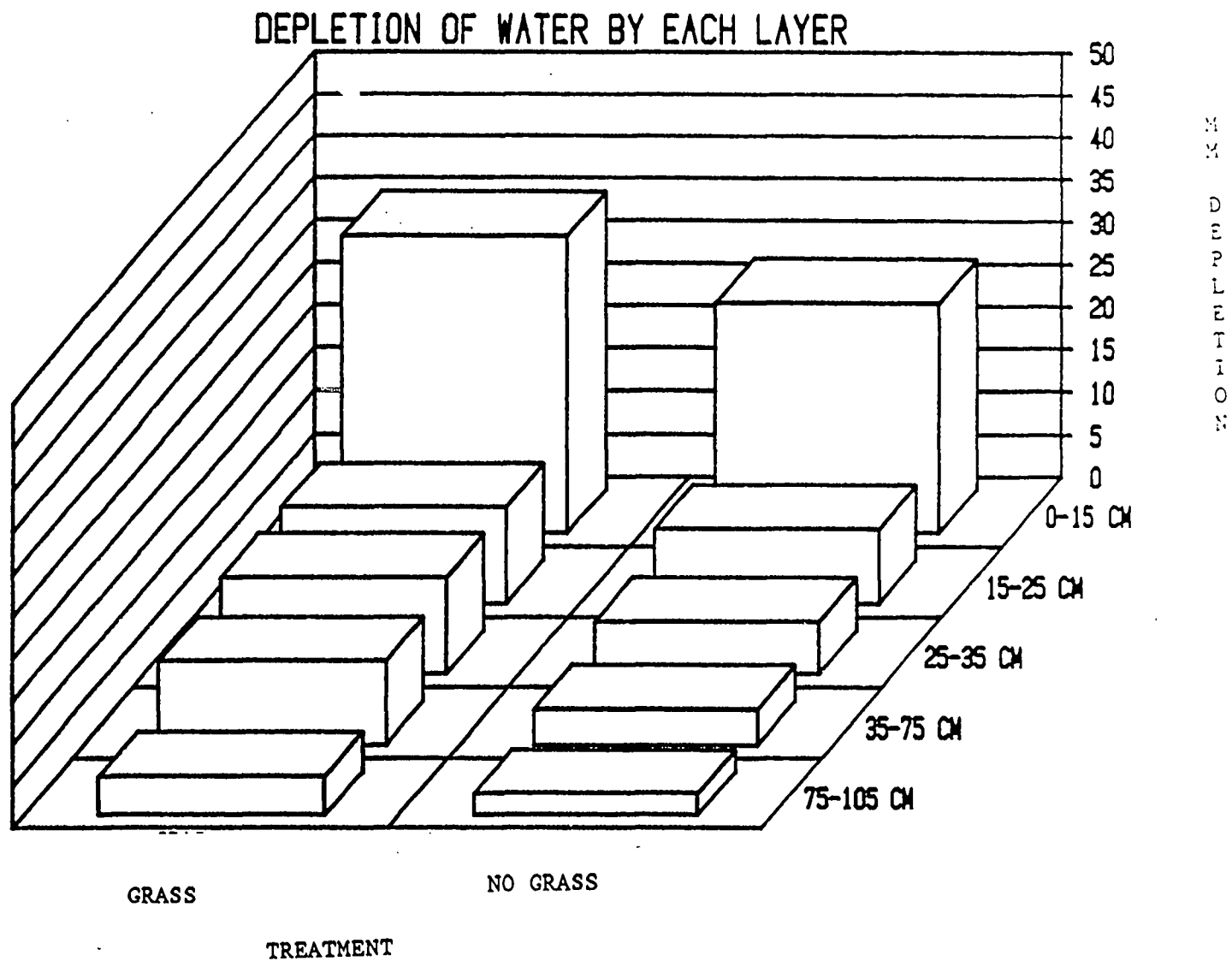
Appendix 8. Total depletion of water in each soil layer under 'Manhattan II' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.

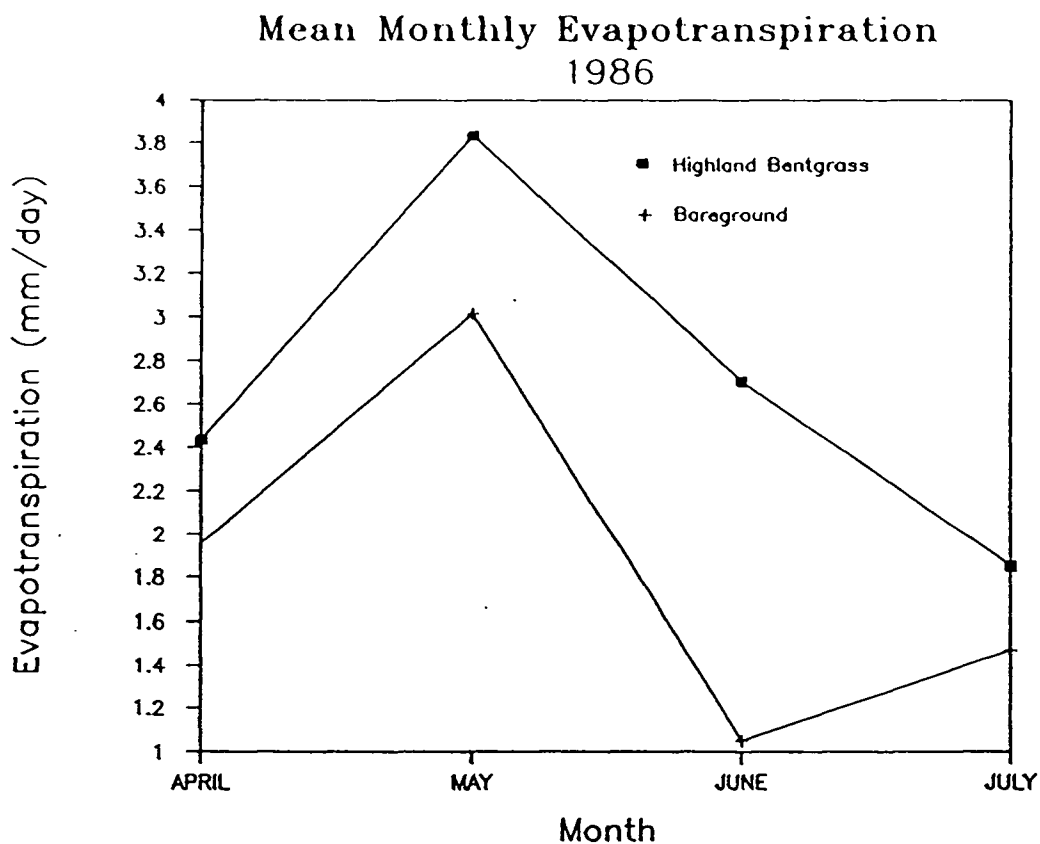


Appendix 9. Total depletion of water in each soil layer under 'Elka' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.

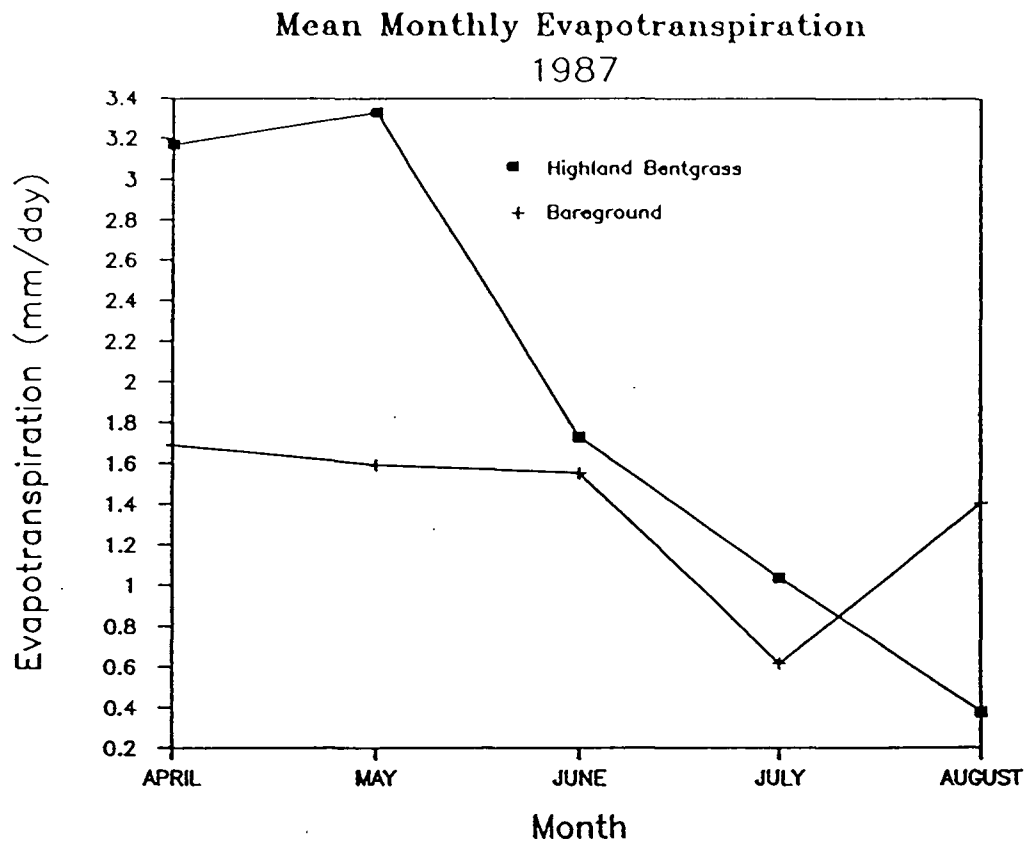


Appendix 10. Total depletion of water in each soil layer under 'Elka' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.

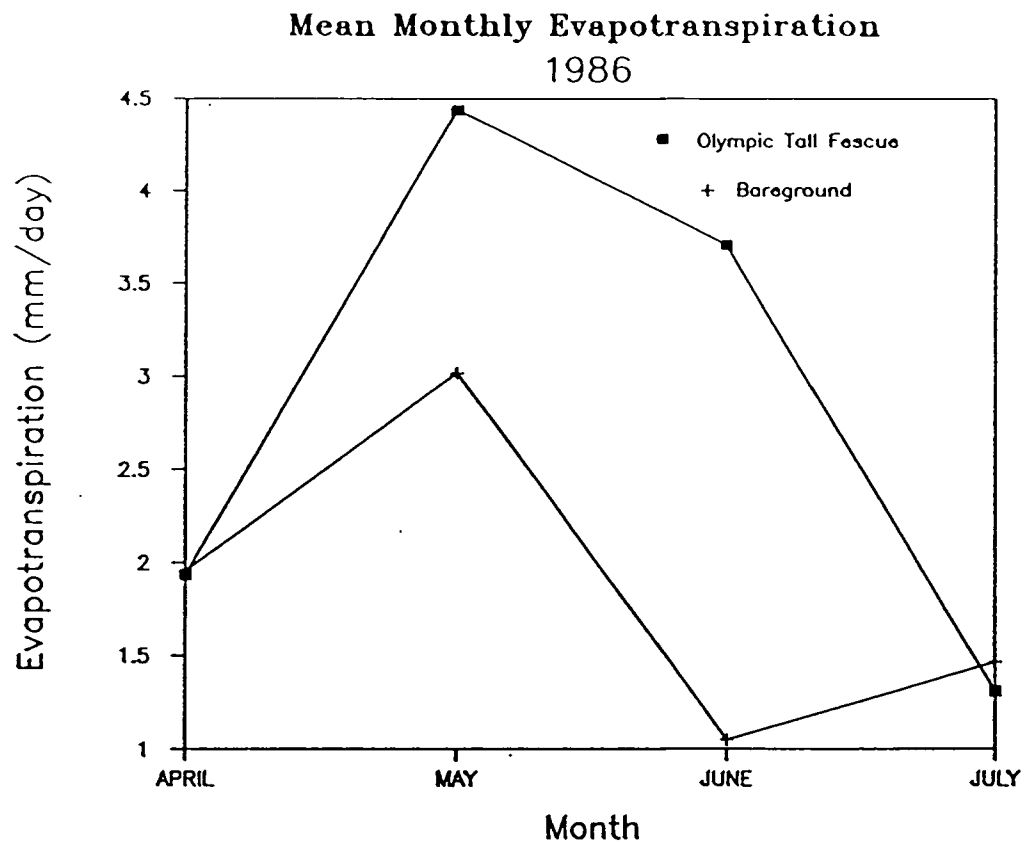




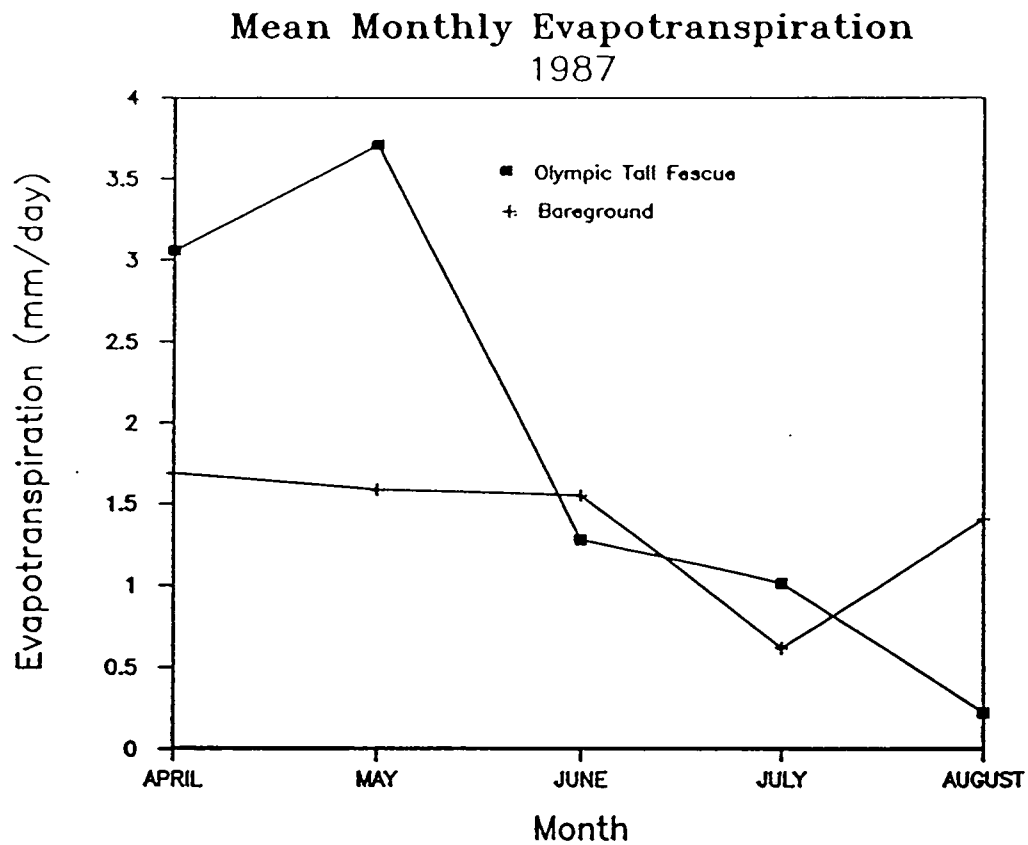
Appendix 11. Average monthly evapotranspiration of 'Highland' bentgrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



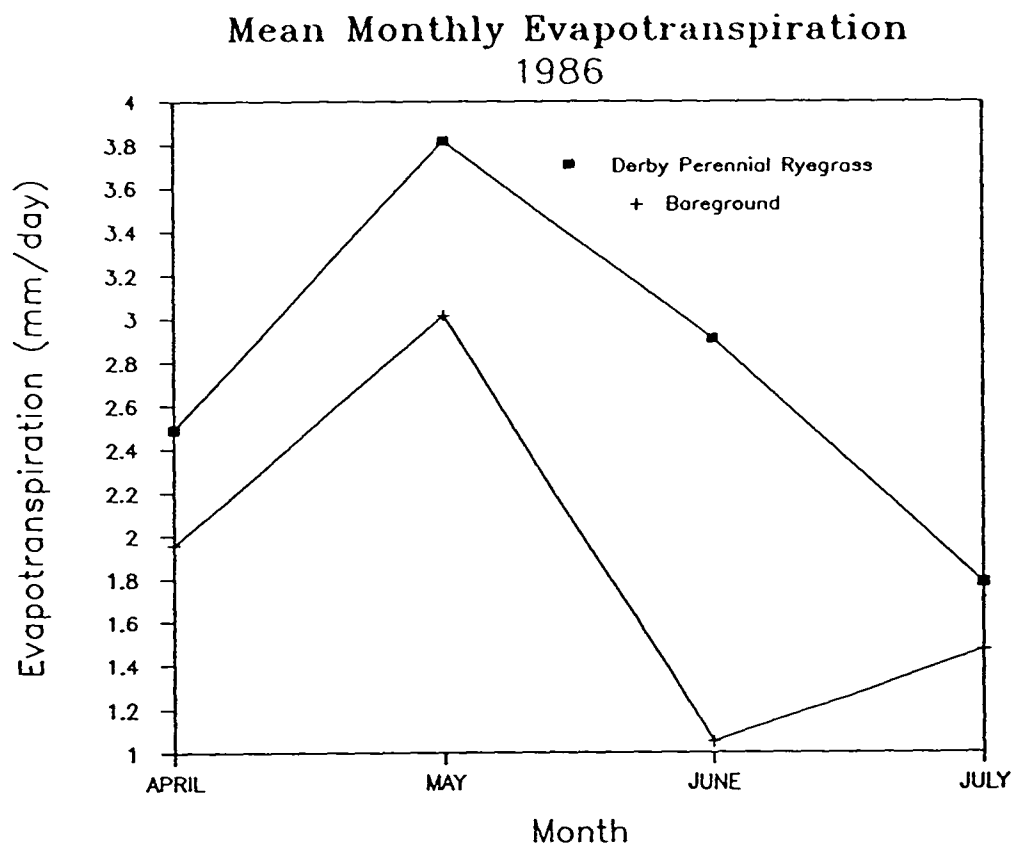
Appendix 12. Average monthly evapotranspiration of 'Highland' bentgrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



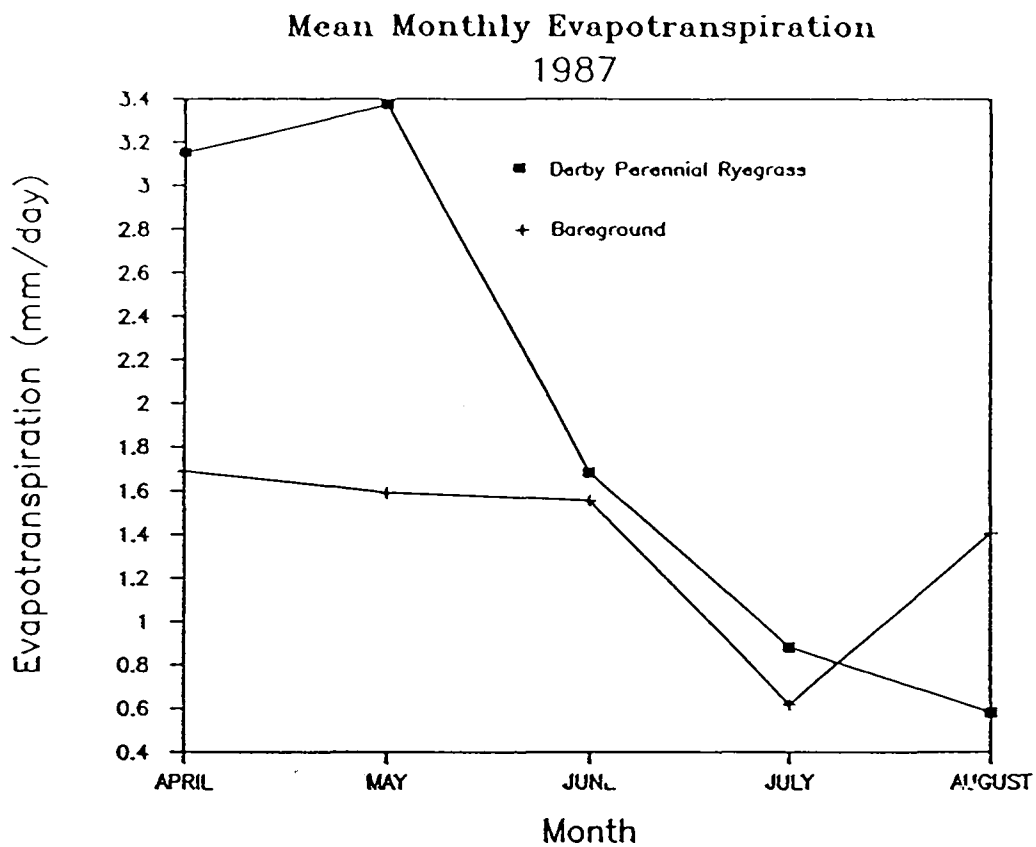
Appendix 13. Average monthly evapotranspiration of 'Olympic' tall fescue on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



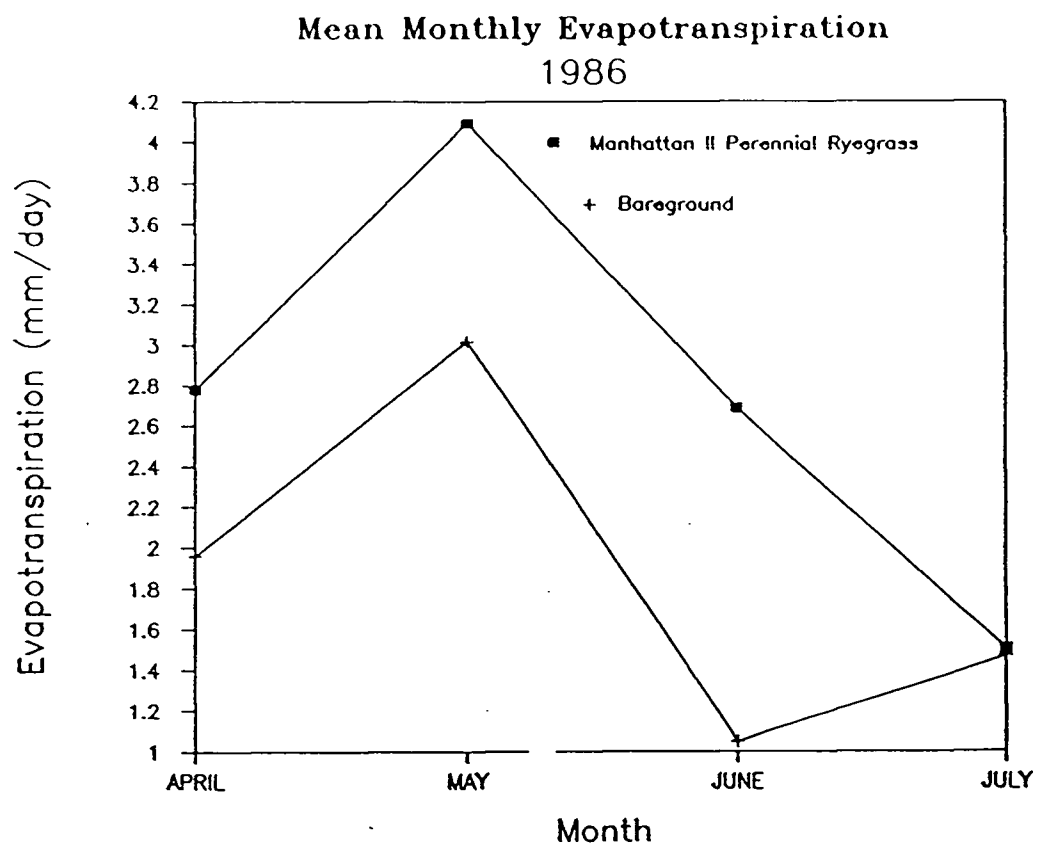
Appendix 14. Average monthly evapotranspiration of 'Olympic' tall fescue on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



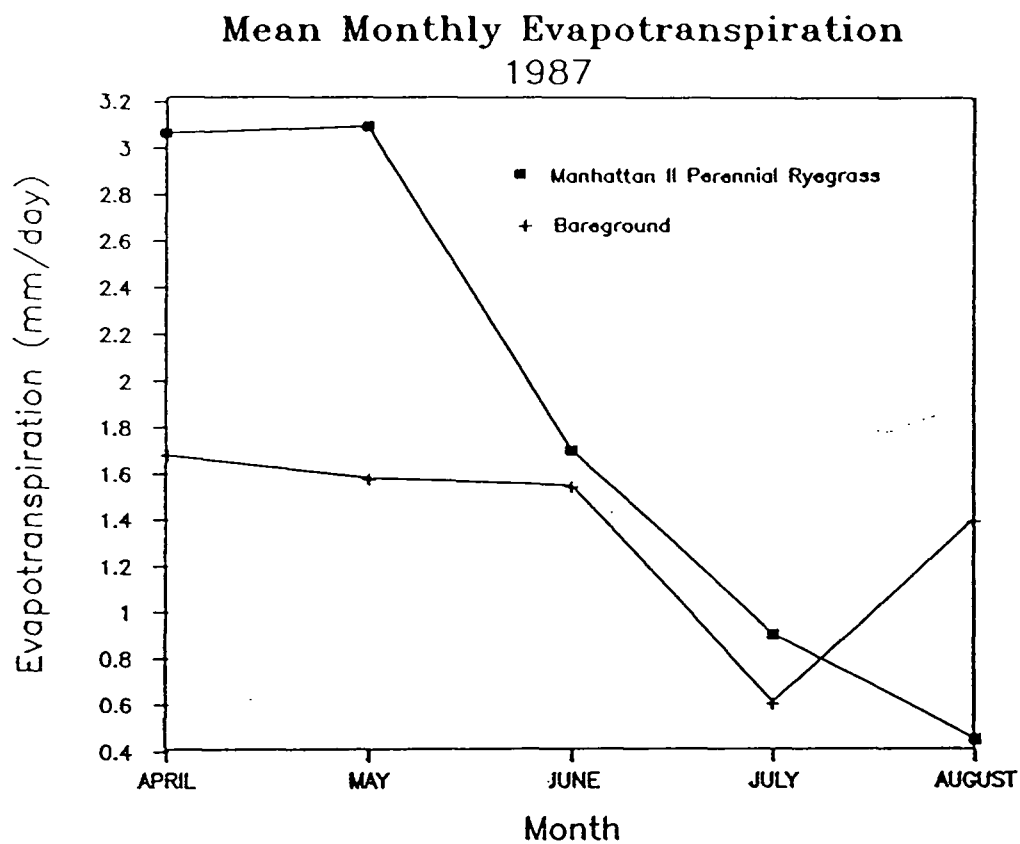
Appendix 15. Average monthly evapotranspiration of 'Derby' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



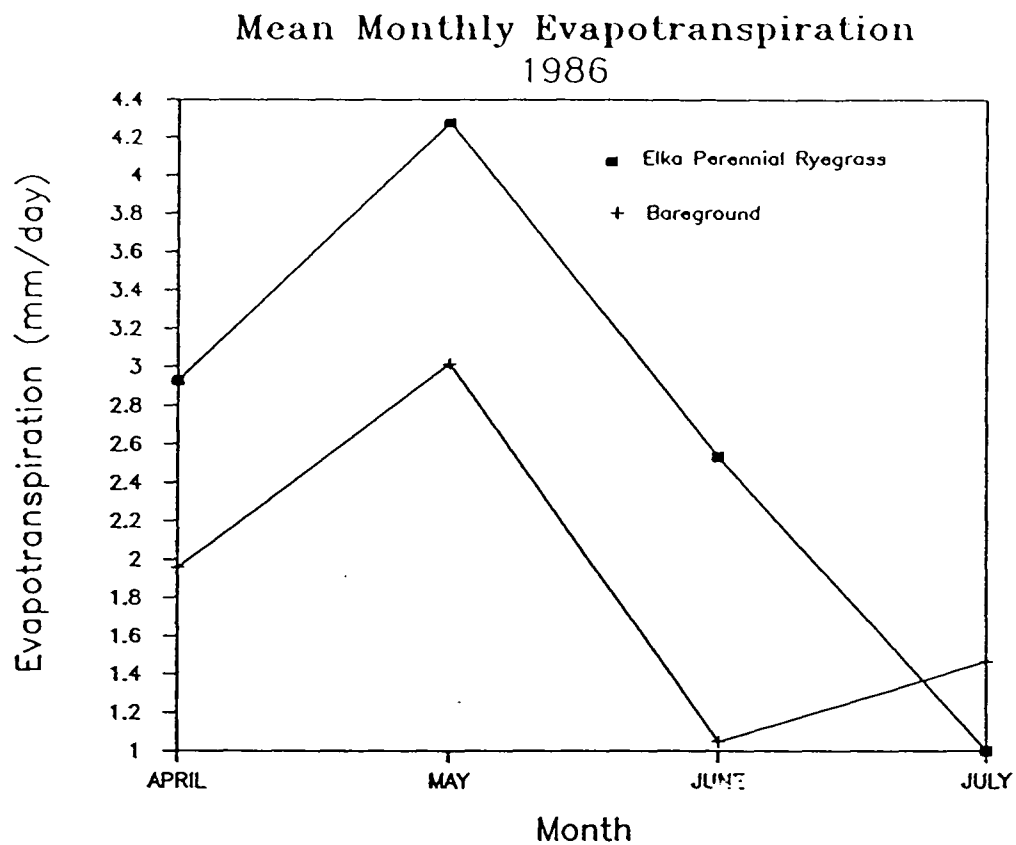
Appendix 16. Average monthly evapotranspiration of 'Derby' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



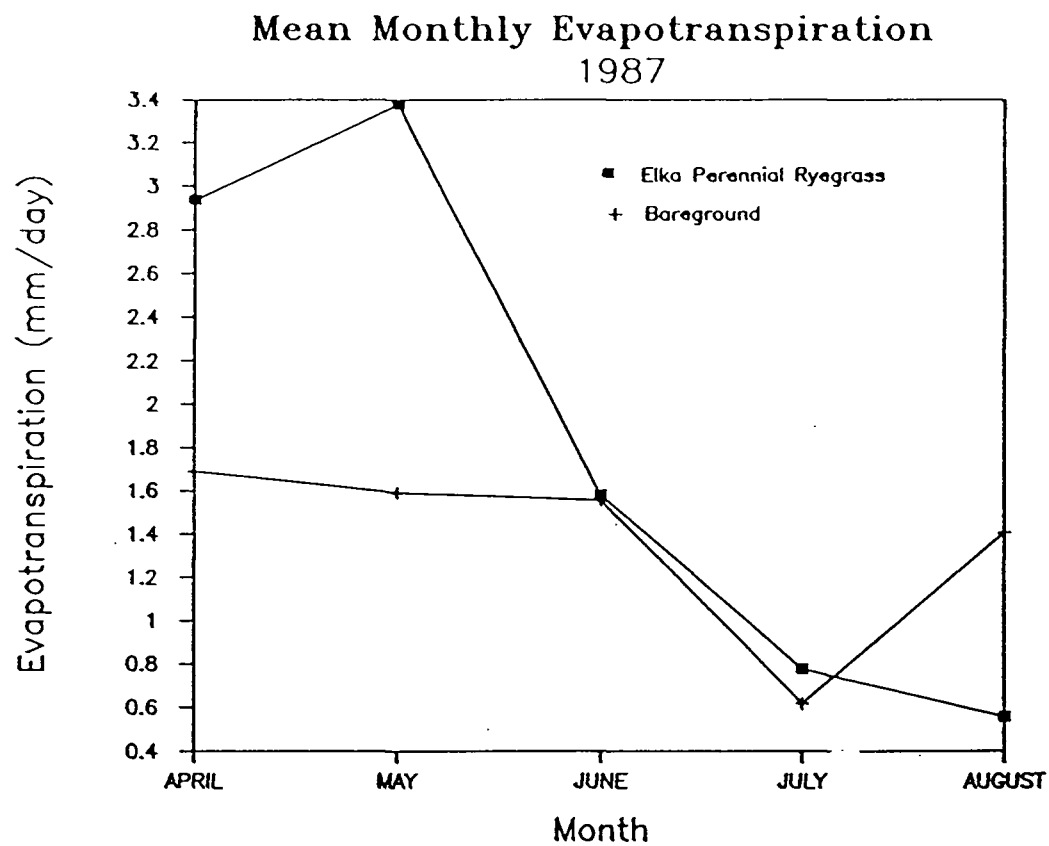
Appendix 17. Average monthly evapotranspiration of 'Manhattan II' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



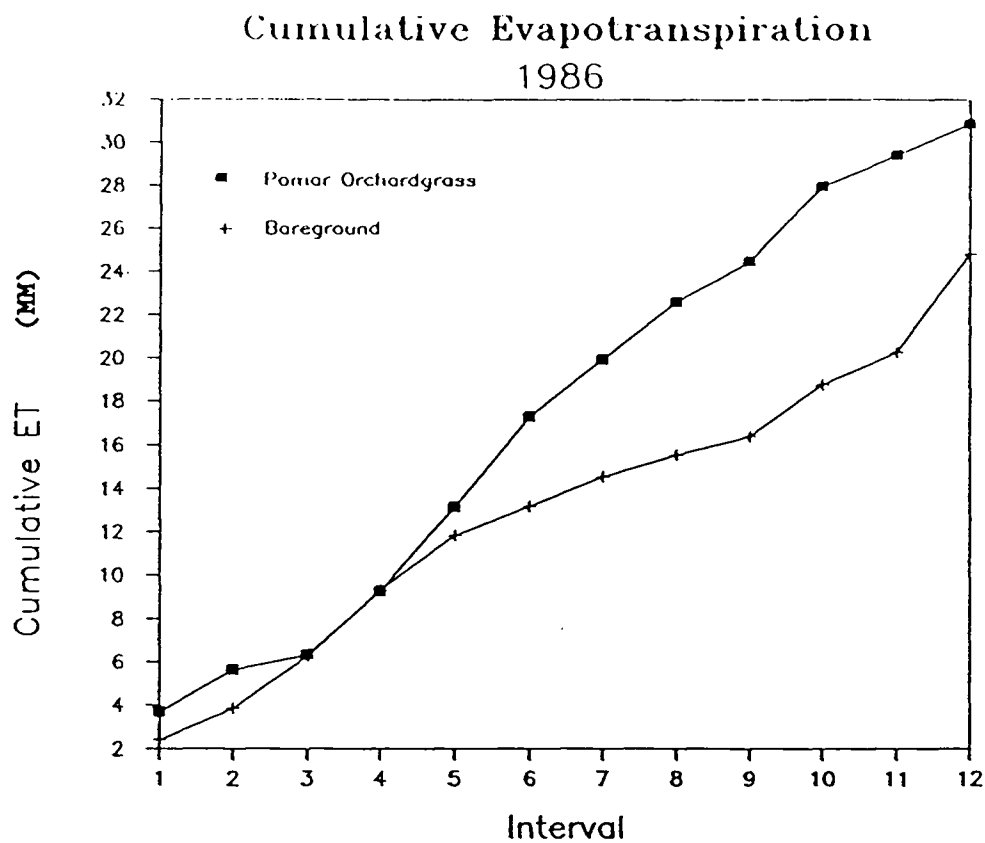
Appendix 18. Average monthly evapotranspiration of 'Manhattan II' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



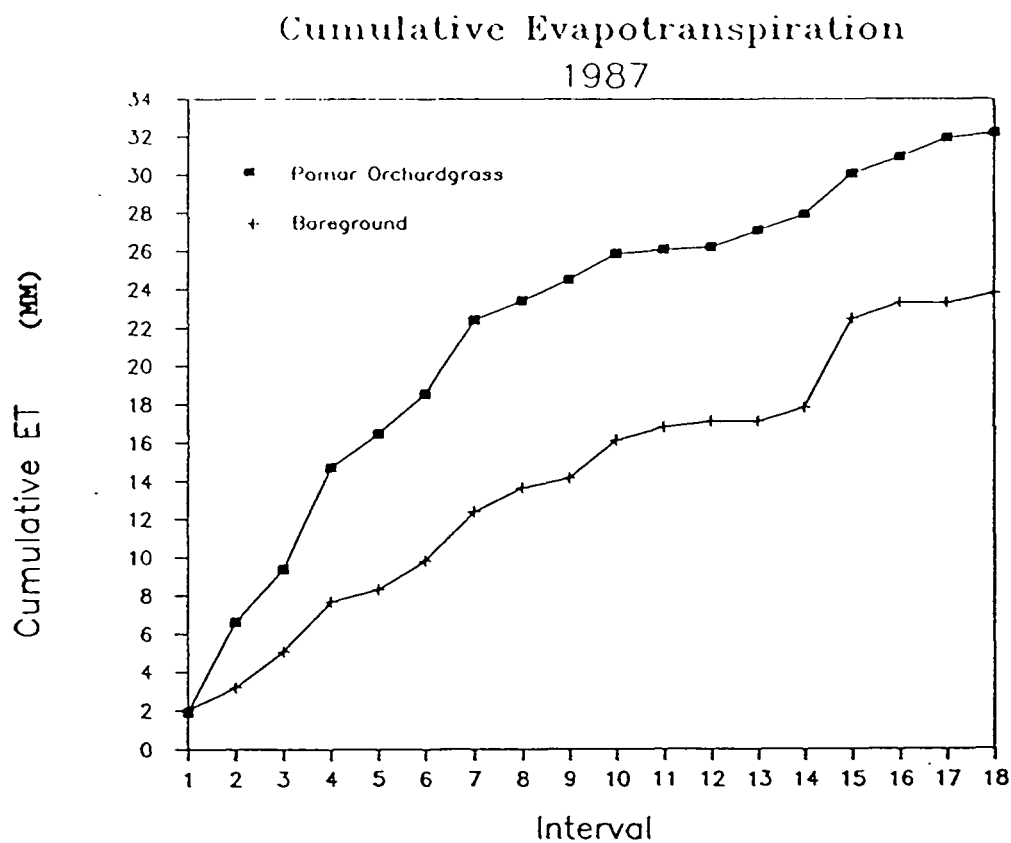
Appendix 19. Average monthly evapotranspiration of 'Elka' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1986.



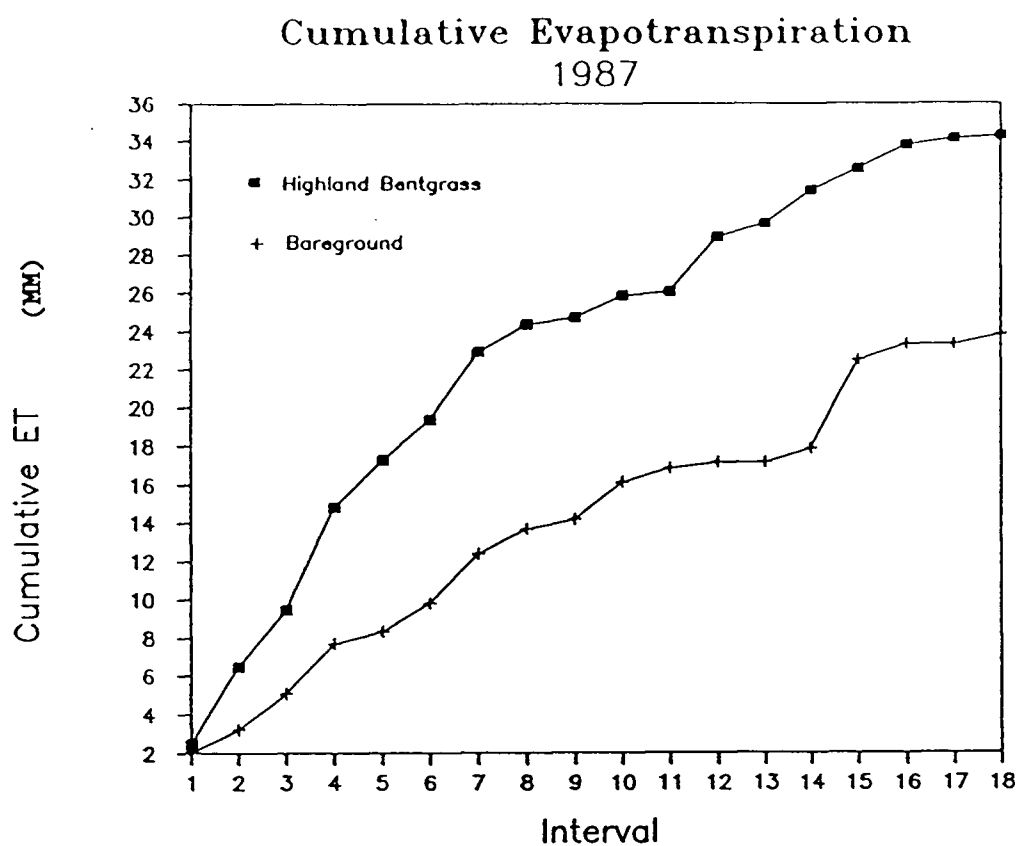
Appendix 20. Average monthly evapotranspiration of 'Elka' perennial ryegrass on Chehalis silty clay loam soil in Corvallis, Oregon, 1987.



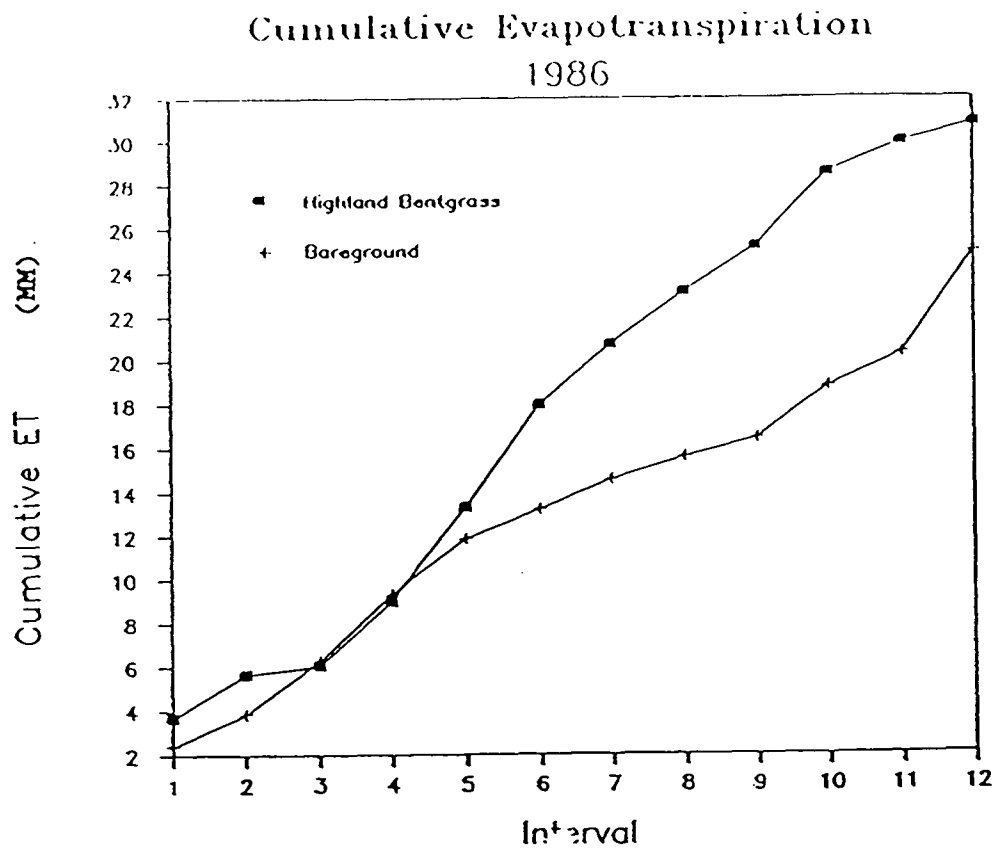
Appendix 21. Cumulative evapotranspiration of 'Pomar' orchardgrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1986. Intervals equal increments of 7-10 days from April 14-July 28, 1986



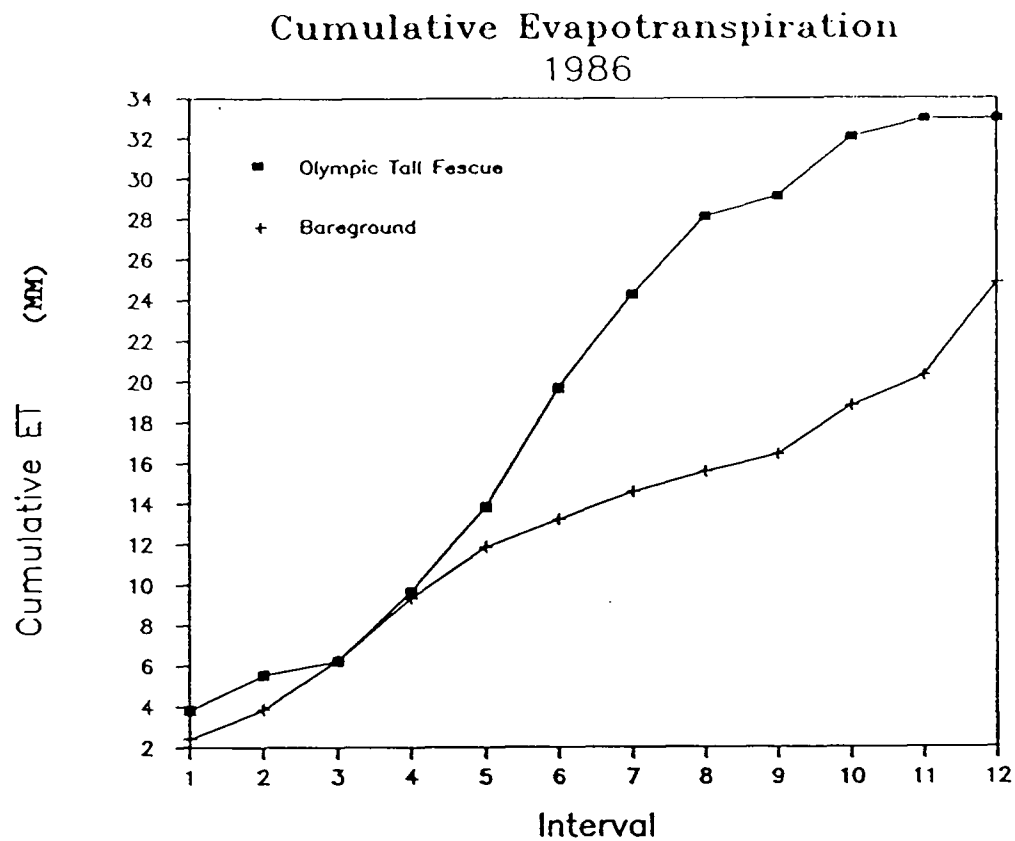
Appendix 22. Cumulative evapotranspiration of 'Pomar' orchard-grass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1987. Intervals equal increments of 7-10 days from April 15-August 27, 1987.



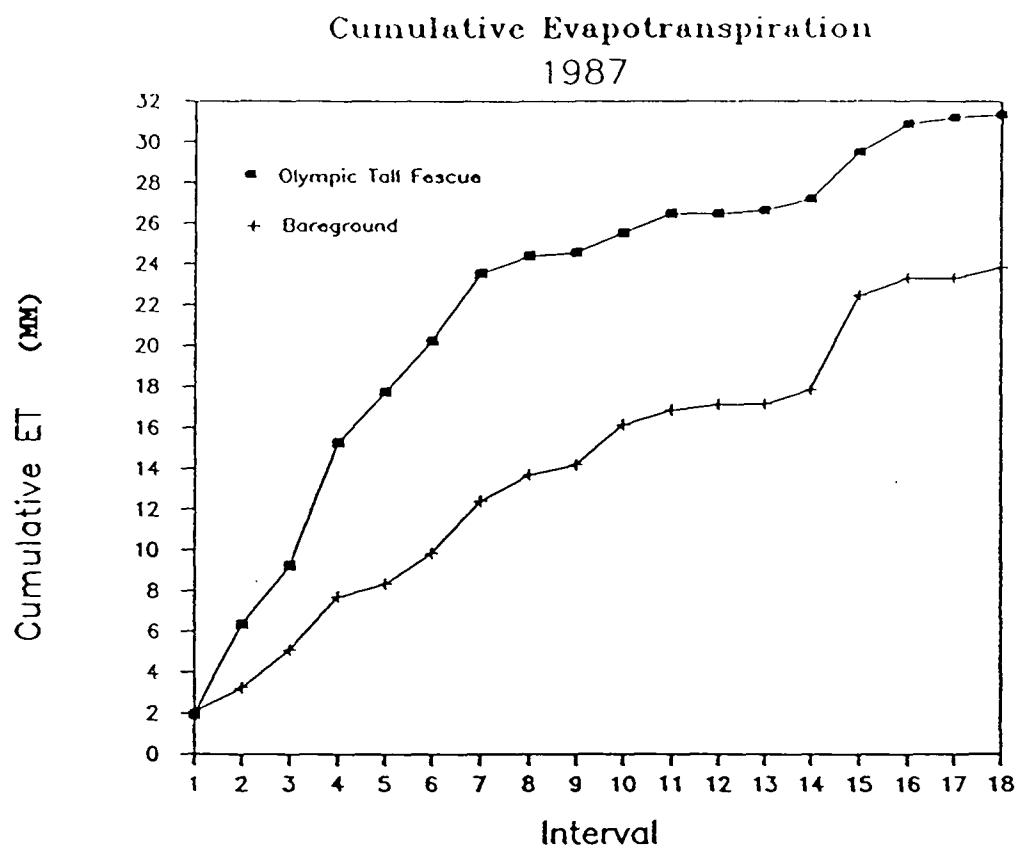
Appendix 23. Cumulative evapotranspiration of 'Highland' bentgrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1986. Intervals equal increments of 7-10 days from April 14-July 28, 1986



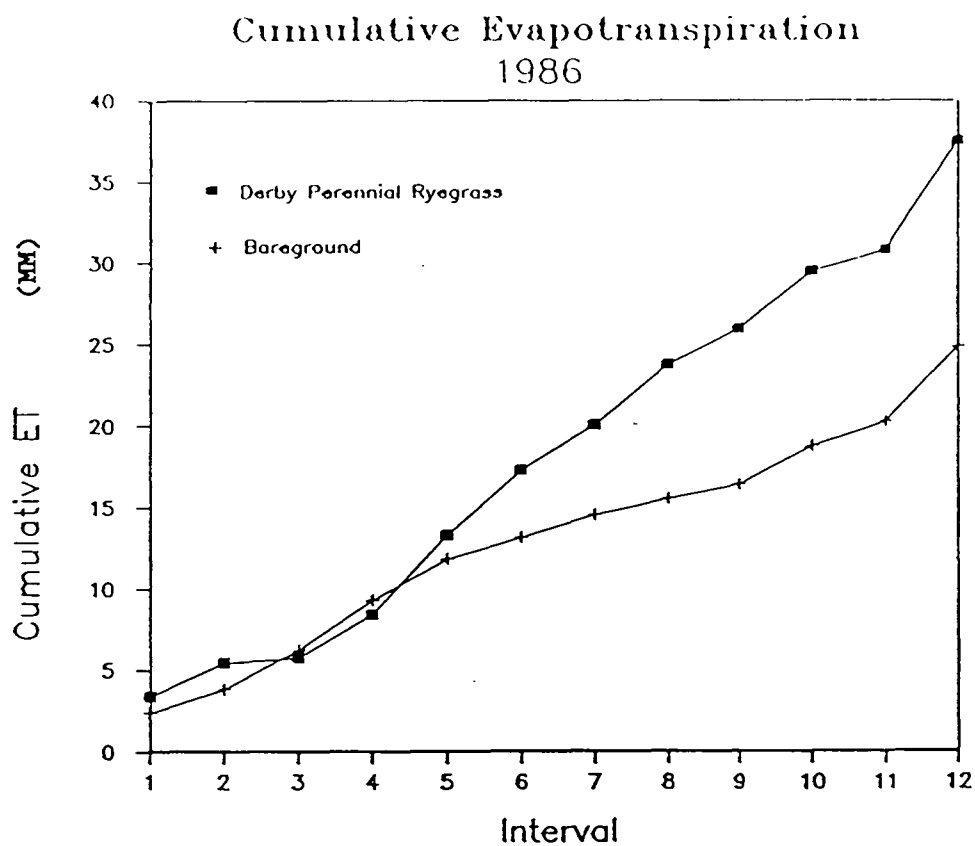
Appendix 24. Cumulative evapotranspiration of 'Highland' bentgrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1987. Intervals equal increments of 7-10 days from April 15-August 27, 1987.



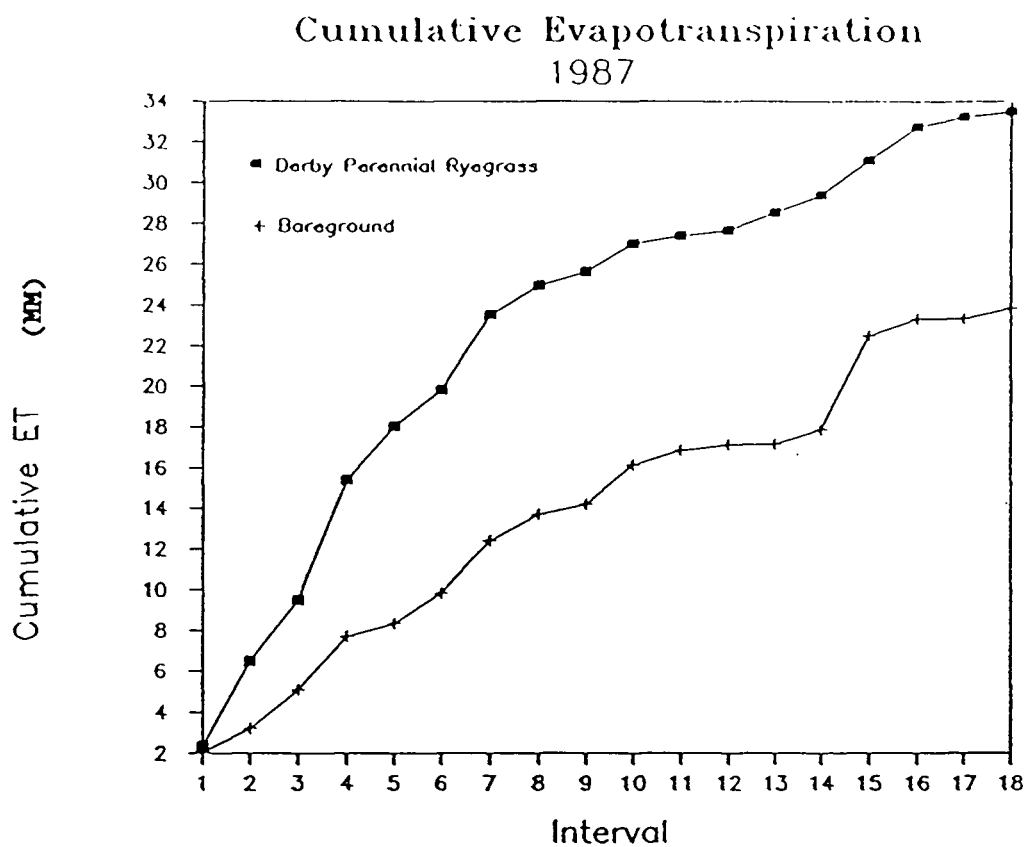
Appendix 25. Cumulative evapotranspiration of 'Olympic' tall fescue and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1986. Intervals equal increments of 7-10 days from April 14-July 28, 1986



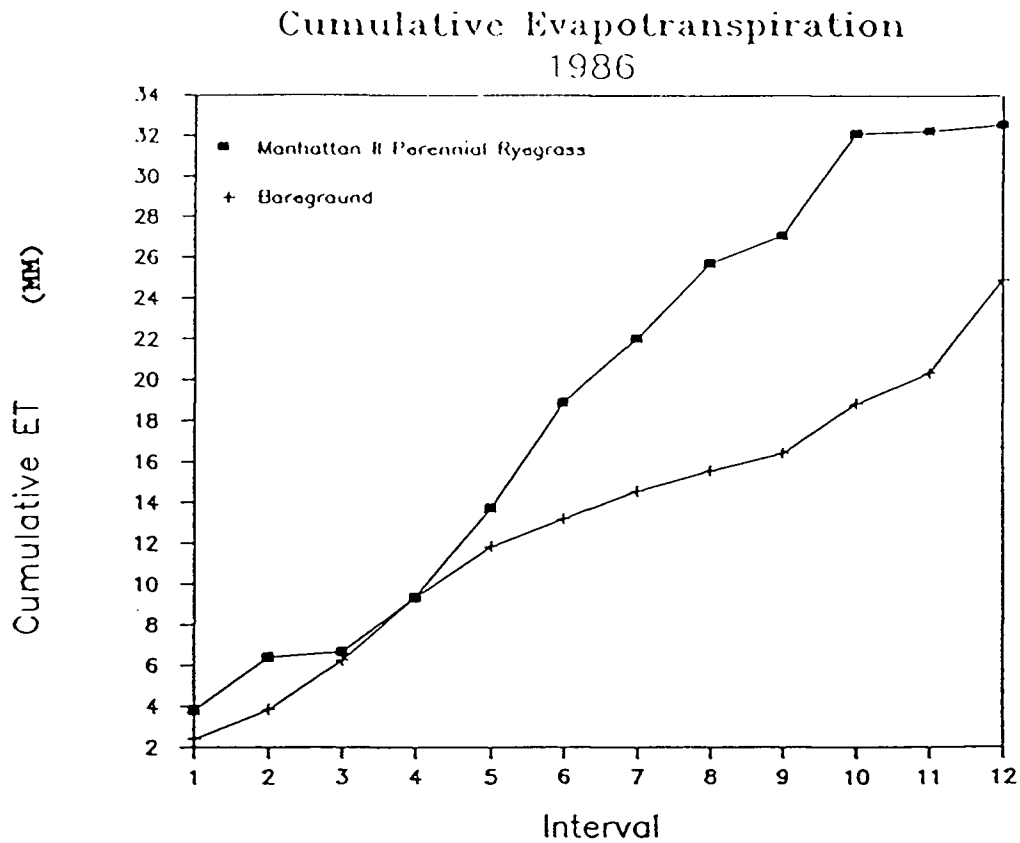
Appendix 26. Cumulative evapotranspiration of 'Olympic' tall fescue and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1987. Intervals equal increments of 7-10 days from April 15-August 27, 1987.



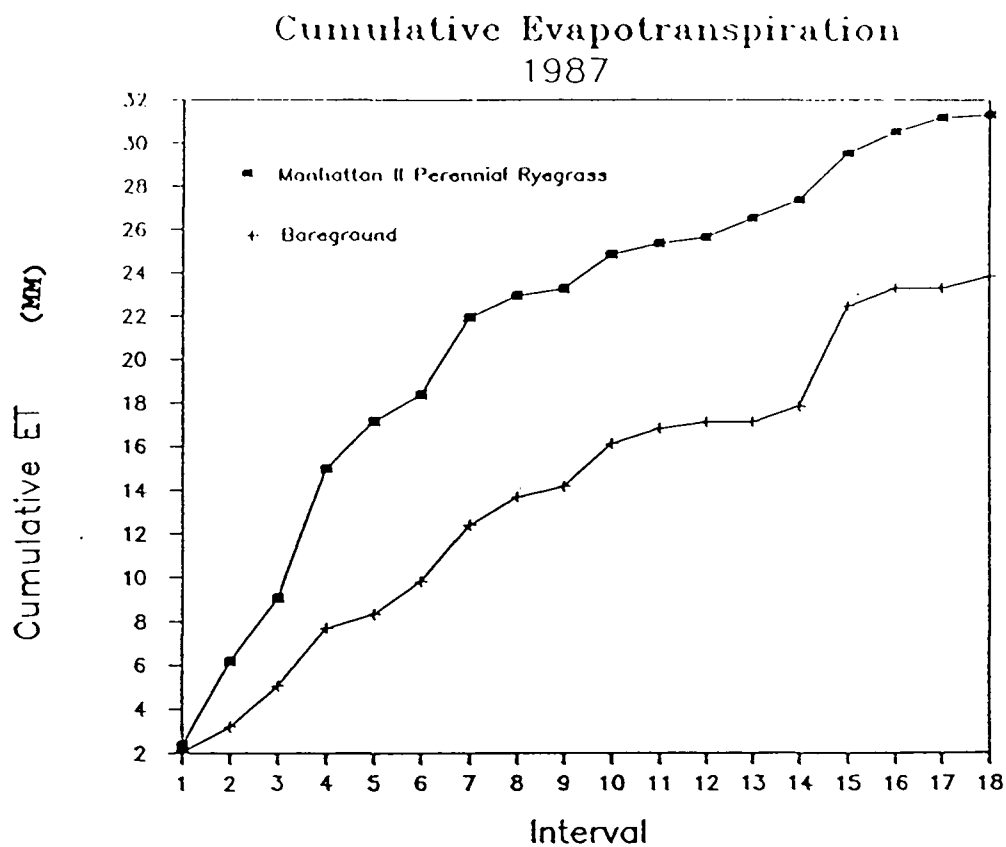
Appendix 27. Cumulative evapotranspiration of 'Derby' perennial ryegrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1986. Intervals equal increments of 7-10 days from April 14-July 28, 1986.



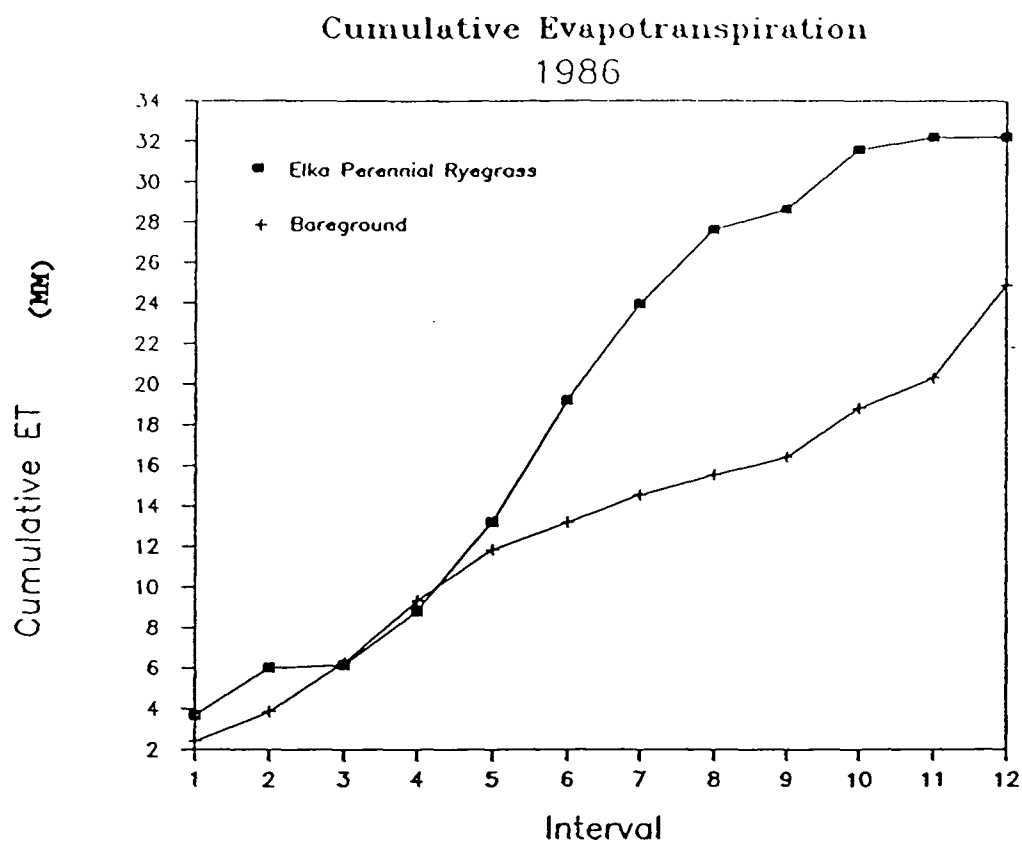
Appendix 28. Cumulative evapotranspiration of 'Derby' perennial ryegrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1987. Intervals equal increments of 7-10 days from April 15-August 27, 1987.



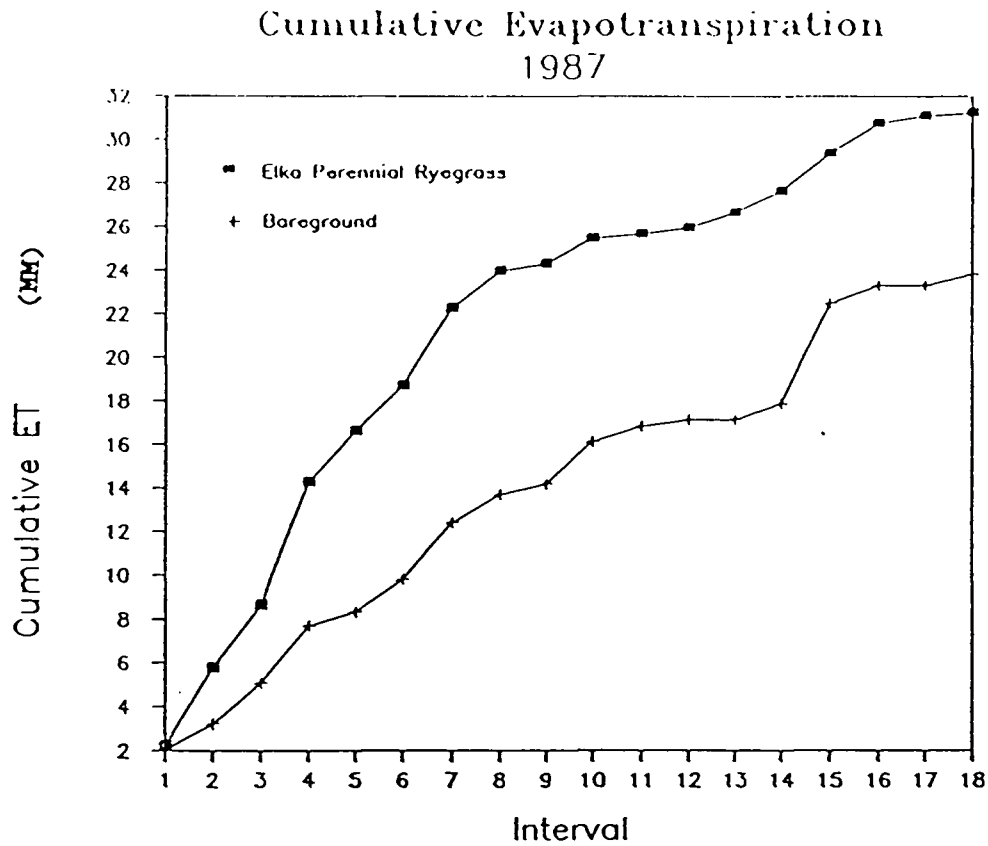
Appendix 29. Cumulative evapotranspiration of 'Manhattan II' perennial ryegrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1986. Intervals equal increments of 7-10 days from April 14-July 28, 1986.



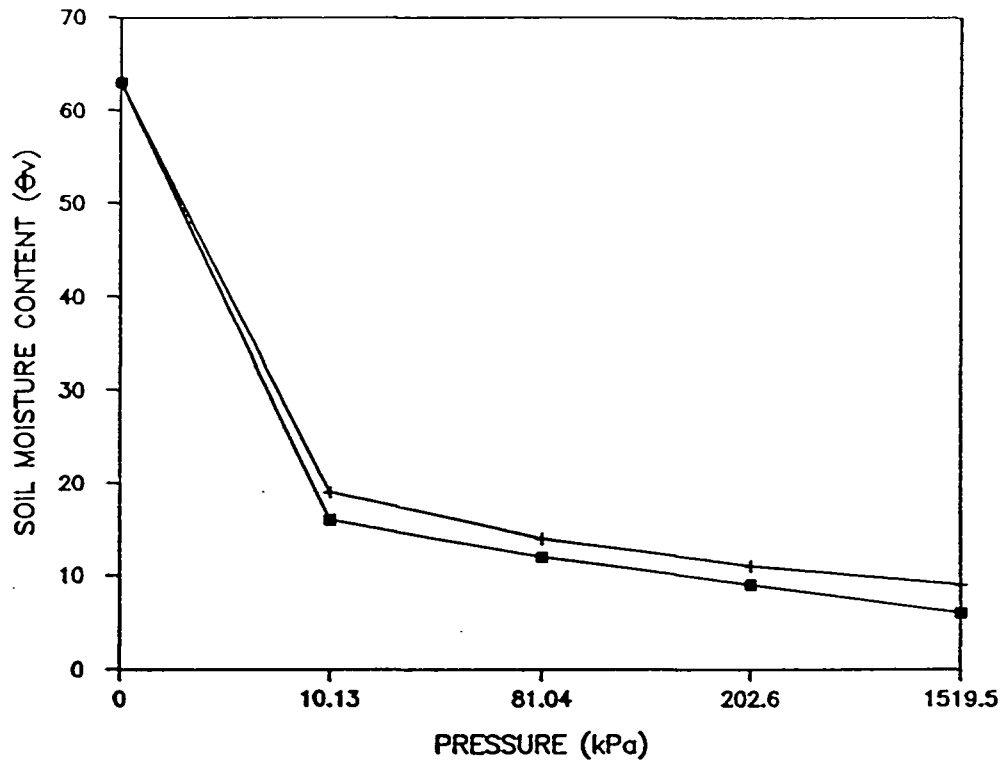
Appendix 30. Cumulative evapotranspiration of 'Manhattan II' perennial ryegrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1987. Intervals equal increments of 7-10 days from April 15-August 27, 1987.



Appendix 31. Cumulative evapotranspiration of 'Elka' perennial ryegrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1986. Intervals equal increments of 7-10 days from April 14-July 28, 1986.



Appendix 32. Cumulative evapotranspiration of 'Elka' perennial ryegrass and bareground on Chehalis silty clay loam soil, Corvallis, Oregon, 1987. Intervals equal increments of 7-10 days from April 15-August 27, 1987.



Appendix 33. Soil moisture retention curve at 0, 0.1, 0.8, 2.0 and 15.0 bars for sand:peat media in greenhouse pot culture experiment, 1988.