# "Development of New Orchard Soil Management Practices for Improving Water Use Efficiency and for Reducing Water Quality Degradation".

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# DEVELOPMENT OF NEW ORCHARD SOIL MANAGEMENT PRACTICES FOR IMPROVING WATER USE EFFICIENCY AND FOR REDUCING WATER QUALITY DEGRADATION

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# SUMMARY

The Rio Grande river and groundwater resources in the Rio Grande basin are vital for economic developments along the Texas-Mexico border as well as for preserving habitats for wildlife species, many of which are on the endangered list. Nitrate ions are one of many contaminants which can cause eutrophication as well as health hazards. Pesticides, particularly those applied to the soil, may also be the source of ground and surface water pollution. As cultivation of fruit crops utilizes liberal amounts of chemical fertilizers and pesticides, this study was undertaken to develop a management system which would minimize the use of herbicides and leaching of nitrates.

Sodding of the orchard floor is used by some fruit and nut growers because of low maintenance costs, improved trafficability and harvesting efficiency. This system may be expected to reduce leaching and/or losses of the pollutants mentioned above. It could also, however, increase competition for water and plant nutrients, thus resulting in less tree growth and yield.

Two lysimeter and one field study were conducted with grapefruit and pistachio trees to test the following set of hypotheses: i) leaching losses of nitrate can be reduced by sodding which immobilizes this anion in the soil; ii) the competition for N can be minimized by selecting sod species whose peak N demands do not overlap those of the fruit trees; iii) the competition for water can also be minimized by selecting the sod species which have low water demands or have the trait of decreasing transpiration under moderate water stress or shade, and iv) the competition for water and nitrogen can be reduced by management which provides a buffer zone

between the trees and sodded areas or by sloping the ground to increase the flow of water and N toward the tree.

In an outdoor lysimeter study with 'Rio Red' grapefruit trees, the highest growth rate was obtained under the bare soil treatment. The presence of cool season grasses such as orchardgrass and wheatgrass, had a more depressing effect on citrus tree growth than warm season grasses such as bahiagrass and buffalograss. This was due to a higher rate of N uptake by cool than warm season grasses early in the season when the tree N demands were also high. Nitrate losses by leaching were 18-28% of the amount applied under the bare ground treatment but they were reduced to just 1-3% under the sod cover during the first two years of sod establishment. Once the sod got established, however, the leaching losses under buffalograss, orchardgrass, wheatgrass, and clover increased and were similar to those recorded under the bare ground treatment. In the bahiagrass treatment, however, the leaching losses were still less than under the bare ground treatment. The competitive effects of sod on tree growth will subside in a mature orchard due to increased shade intensity between the tree rows which reduces the growth of sod and consequently the use of water and nutrients.

In another lysimeter study, pistachio seedlings were grown outdoors under various floor management schemes to evaluate nitrate leaching losses and sod/tree competition. During the year of tree and sod establishment, the floor management options included clean cultivation and partial sodding with buffalograss between tree rows under the flat and sloped (1.8%) ground surfaces. Partial sodding with buffalograss reduced nitrate leaching losses from 11 to 5-6%, while presenting no adverse effects on growth of the pistachio seedlings. During the 2nd growing season, two cool season species (clover and orchardgrass) were established between the buffalograss strips and the tree rows as two additional treatments. Partial sodding with buffalograss (without clover or orchardgrass) reduced nitrate leaching from 23% to less than 11% and the full sodding involving buffalograss and clover or orchardgrass lowered nitrate leaching losses down to less than 6%. However, all sodded treatments, particularly those with cool season species, reduced seedling tree growth by nearly 50%. Surface sloping had no major effect on plant growth but increased nitrate leaching somewhat. In the third growing season, partial sodding with buffalograss was ineffective in reducing nitrate leaching compared to non-sod plots where 22 and 31% of the nitrate leached under the flat and sloped ground surface, respectively. The complete sodding with buffalograss and clover, and the combination of buffalograss and mulch reduced nitrate leaching to 15% under the flat ground treatment but sods were ineffective in reducing nitrate leaching when the ground was sloped. Sodding presented no major reduction in pistachio tree growth in the 3rd year of study, except under the complete sodding treatment with buffalograss and clover.

The studies conducted in lysimeters indicated that sodding is effective in reducing nitrate leaching losses while the sod plants are actively growing (as during sod establishment) and taking up large quantities of nitrogen. Once the N demand of the sod is met, the use of ground cover vegetation for reducing nitrate leaching appears limited. In this instance, the soil management system used must facilitate the storage of N in soils which can help reduce the peak nitrate concentrations in drainage water.

In a field study with 'Rio Red' grapefruit the effect of partial sodding with King Ranch bluestem grass on nitrate leaching and tree growth were studied over a 3-year-period. The orchard floor management options included overall herbicide (OH) (a current standard practice), and partial sodding with 1.2 m-wide (G) or 2.4 m-wide (HS) herbicide strips within the tree rows. Irrigations with microsprinklers were initiated at 20 cb soil water suction as measured with tensiometers at 30 and 60 cm depth. Microsprinkler irrigations resulted in nitrate concentrations in a shallow ground water well below the primary drinking water standards of 10 mg $NO_3$-N/liter irrespective of soil management. The presence of sod in the orchard reduced the level of nitrate in the ground water two years after treatment but this effect ceased to exist in the third year of study which concurs with the results obtained in the lysimeter studies. The presence of sod had a dwarfing effect on trees but had no negative effect on fruit yield. Consequently, yield efficiency, expressed as the amount of fruit per unit of canopy volume, increased when the sod was present. This dwarfing effect could possibly aid in managing high density plantings to reap increased orchard production per unit of surface area. Compared to OH system, the presence of sod reduced the amount of herbicide used by 84% and 66% in the HS and G treatments, respectively, and resulted in an overall reduction of weed control cost by 42% and 52%. However, the sod increased irrigation amounts compared to OH system but the cost of this additional water was very small compared to savings on herbicide use in sodded vs. unsodded plots. It was estimated that the use of microsprinkler irrigation in a young grapefruit orchard resulted in 82%, 75%, and 67% savings of irrigation water in the OH, HS, and G treatments, respectively, compared to traditional flood irrigation over a weed-free citrus orchard floor.

# GENERAL INTRODUCTION

The Rio Grande river and groundwater resources in the Rio Grande Basin are vital for economic developments along the Texas-Mexico border areas as well as for preserving habitats for wildlife species, many of which are on the endangered list. There are, however, increasing numbers of indications to suggest that quality of these water resources is deteriorating (e.g., Miyamoto et al, 1993). Nitrate ions are one of many contaminants which can cause eutrophication as well as health hazards. Although the extent of $NO_3$ pollution caused by agricultural activities is believed to be relatively confined, there are cases of high $NO_3$ in ground water (e.g., Pennington, 1990), some of which may be related to fertilizer sources and/or disposal of poorly treated human and animal wastes or to petrogenetic sources.

Tree crops, especially citrus and nut crops, have traditionally provided a large portion of farm income and associated economic activities along the Rio Grande. The production of these crops, however, requires high levels of input, namely water, fertilizer and various types of pesticides. There has been an increasing concern that this production activity may be contributing to water quality degradation, especially through leaching or runoff of chemical fertilizers. One of the ways to reduce $NO_3$ leaching losses is to improve water management. The study conducted in the Lower Rio Grande, for example, shows that trickle irrigation of citrus reduced $NO_3$ leaching as compared to flood irrigation (e.g., Swietlik, 1995). This method of irrigation is also used with some success in young pecan orchards in far west Texas. However, trickle irrigation is rarely used in mature pecans mainly because this method does not provide an adequate coverage of water application when the root system of pecans spread throughout the orchard floor. Sprinklers usually offer better water application patterns. In the case of citrus, growers are interested in microsprinklers, because of their freeze protection capability. However, there are currently no data on water requirements and $NO_3$ leaching losses in citrus orchards irrigated with microsprinklers in citrus orchards of the Lower Rio Grande Valley.

Another potential method of reducing both leaching and runoff losses of agricultural chemicals is to provide vegetative covers on the orchard floor. Currently, most orchards utilize clean cultivation using disking and herbicides as the primary tools. Some growers, however, have converted floor management to sod covers, mainly because mowing is usually cheaper than disking or applying herbicides. In addition, sodding improves trafficability for orchard maintenance and provides the habitats for beneficial insects for biological control of pests. In addition, the presence of vegetative covers has been recognized to provide filtration of suspended particulates from runoff water, which contain a large portion of the pesticide residues (e.g., Schellinger and Clausen, 1992), reduced leaching losses of N fertilizers through immobilization (e.g., Jackson et al., 1993; Weier and MacRae, 1993), and increased denitrification through increasing soil organic matter contents through microbial activities (e.g., Trudell et al., 1992). Under certain conditions, sodding may also improve soil physical conditions and water infiltration (e.g., Glenn and Welker,1989; Folorunso et al., 1992).

In spite of these potential benefits, sodding is also known to induce the competition for water and plant nutrients. Covering the entire orchard floor with sod reduced tree growth and yields of apples (Miller, 1983; Neilsen et al., 1984) and peaches (Welker and Glenn, 1989). However, sodding with certain types of vegetative covers such as legumes did not significantly affect growth and nut quality in pecans (Apel et al., 1979; Goff et al., 1991). Partial sodding of the center strip between tree rows or sodding after the peak shoot and leaf growth stages did not significantly affect growth and yields of peaches (Layne and Tan, 1988). In some instances, the presence of sod killed by herbicides promoted growth of young peach trees (e.g., Welker and Glenn, 1988). Sodding is also known to increase water use, especially in young orchards, although the extent of the increase had not been clearly defined.

It is thus apparent that successful sodding must balance two opposing factors; one to encourage N immobilization to reduce $NO_3$ leaching, and another to minimize competition for water and nitrogen. This may be accomplished, in part, by selecting sod species whose peak demands for N do not excessively overlap those of the trees or by providing management which helps bring about the balance. The competition for water may be reduced by selecting species which have either low water demands or a tendency towards reduced transpiration under moderate water stress or shade conditions or by imposing management to help attain the balance.

The studies reported here were conducted to evaluate 1) growth, water use and nitrogen uptake characteristics of five ground cover species which have a potential for orchard sodding (Study I), 2) sod management strategies to minimize competition for nitrogen and water while containing N leaching losses and water requirements (Study II), and field performance of sodding in a microject irrigated citrus in the Lower Rio Grande (Study III).

# I. EFFECTS OF SODDING ON DRAINAGE WATER QUALITY, TREE PLANT NUTRIENT UPTAKE AND WATER USE

**Lloyd Fenn, Texas A&M University Agricultural Research Center, El Paso, Texas.**

## 1. Introduction

It was discussed in the general introduction that a sodded floor is cheaper to maintain, and will help improve trafficability, water infiltration and harvesting efficiencies. Sodding can also reduce leaching or runoff losses of $NO_3$ and pesticides and provide habitats for beneficial insects. In spite of these potential benefits, sodding is also known to increase competition for water and plant nutrients. When a sodded floor is not managed properly, sodding can severely reduce tree growth and crop yields (e.g., Miller, 1983; Neilsen et al., 1984; Walker and Glenn, 1989). The competition for N appears to be the most frequent cause (e.g., Neilsen et al., 1984), but sodding can also restrict tree root developments as well (e.g., Glenn and Welker, 1989; Welker and Glenn, 1989; Parker et al., 1993).

Although many options to overcome the competition (such as partial sodding, frequent mowing, etc.) have been suggested, we currently do not have a systematic strategy to minimize the competition, while achieving the benefits of sodding. One of the strategies that can be used is the selection of sod species whose peak N demands do not excessively overlap with the peak N demands of the trees. Another strategy may be to use sod species whose growth and water demands are comparatively low and can be easily altered by water stress or shade. To assess the workability of these strategies, it is necessary to evaluate growth, N uptake, and water use characteristics of grass or legume species which have a potential for orchard floor sodding. This study was conducted to obtain such information for some selected species, along with the evaluation of the effectiveness of reducing $NO_3$ leaching losses and the competition with citrus trees.

## 2. Materials and Methods

Two warm season grass species (Buffalograss, Buchloe dactyloides cv. Texoka, and Bahiagrass, Paspalum notatum cv Pensacola), two cool season grass species (orchardgrass, Dactylis glomcrata cv. Potamac and Western wheatgrass, Agropyron Smithii Rydb cv. no variety stated) and a legume (white clover, Trifolium repens cv. New Zealand) were selected, mainly based on their proven performance and the ease of establishment. Buffalograss has been used as a low maintenance turf in semi-arid areas (e.g., Feldhake et al., 1984), and bahiagrass in more humid areas (e.g. Busey, 1992). Western wheatgrass has been used as forage both under irrigated and nonirrigated conditions and is tolerant to salts. Orchardgrass and white clover historically already have been suggested for orchard floor sodding.

An outdoor lysimeter experiment was used to obtain growth, N uptake and water use data, mainly because this technique offers good control of water and N balance. The lysimeter assembly consisted of 24 concrete compartments measuring 1 x 1.3 m and 1 m deep. Each compartment was equipped with a drain port and a neutron probe access tube. Eighteen out of 24 compartments contained Gila sandy loam (calcareous, coarse-loamy, mixed, calcareous, thermic Typic Torrifluvent) and the remaining six compartments Bluepoint loamy sand [calcareous, loamy, thermic (not formally classified)], both to a depth of 1 m. Prior to the present experiments, these soils were leached with a local tap water until salinity of the drainage water decreased below 1.5 dS $m^{-1}$.

In June, 1992, 2-year old citrus grapefruit trees (Citrus paradisi; Macf, cv. 'Rio Red', 40 cm tall) on sour orange rootstock (Citrus aurantium, L.) were planted as an indictor of sod induced-competition. The four grass species were planted approximately on 1 July and clover on 1 September 1992 with the treatments outlined in Table I-1. The experiment was arranged in a random design in triplicate. During 1994, a shade screen was placed over the plant canopy to reduce sunlight penetration by 40%, measured by a pyronometer. Also, the lysimeter assembly was covered with a plastic cover during December, January, February and March to protect citrus trees from cold weather.

Nitrogen fertilizer, as ammonium sulfate, was broadcast at the rates specified in Table I-1. The application was then followed by irrigation within a day to minimize volatile losses. Irrigation was made when the soil water storage was reduced by 40 to 50% to provide the target leaching fraction of about 20%. The soil water depletion was measured with a neutron probe at different depths. An exception to this guideline was made in June of 1994, when soil water was deliberately allowed to deplete below 50% of the storage capacity for the purpose of observing the reduction in transpiration rates under water stress. During this period, neutron probe readings were taken every 3 to 4 days.

Sod growth was evaluated by periodic mowing-harvesting 5 cm above the ground. The harvested sods were dried at 60°C and the dry weights recorded and N contents determined by the method of Bremner (1965). The sod samples were ground and returned to each lysimeter. Fresh sod subsamples were also determined for leaf area with a scanning integrator, and the relationship between leaf area and sod dry weights determined. Nitrogen uptake by sods was estimated as a product of dry weight and N concentrations. Water use (evapotranspiration) was determined from the measurement of irrigation and drainage quantities and soil water depletion measured with a neutron probe. Soil water depletion pattern was determined from the soil water depletion measured at different depths. The Pan Evaporation data (1.2m US Weather Bureau pan) were collected at a nearby station.

Drainage quantities from the lysimeters were determined and $NO_3$ concentration determined by the phenyldisufonic acid method after each irrigation (USDA, Handbook 70, 1954).

Growth of citrus trees was measured by counting the number of leaves. Twelve leaf samples were also collected in October, 1993, and five times during 1994, and analyzed for leaf area, dry weights and N contents. The total leaf area, dry weight and N uptake per tree were estimated by multiplying the number of leaves per tree and the average leaf area, dry weight and N uptake per leaf, respectively.

Statistical analyses were performed by the procedures outlined in Steel and Torrie (1960).

## 3. Results

### a. Sod Growth and N Uptake

Annual dry sod clipping weight, cumulative leaf area of fresh clippings, annual weighted mean N concentration of sod clippings, and annual N uptake by sods are summarized in Table I-2. During 1992, the year of sod establishment, buffalograss and wheatgrass have produced comparatively large dry top mass, followed by orchardgrass. Bahiagrass and clover produced lower dry mass than other species. Clover was seeded later than others, and there was not enough heat units to grow bahiagrass. During 1993, both of the warm season grasses produced large quantities of biomass, followed by wheatgrass, a cool season grass. Dry matter production of clover and orchardgrass was comparatively low. In 1994, shade was imposed using a shade screen to simulate growth of vegetation under a tree canopy or between trees where some degree of shade frequently exits. Overall growth was greatly reduced. Bahiagrass was the largest dry matter producer followed by buffalograss with all other grasses producing only small quantities.

The rate of clipped sod dry matter production (which is the slope of the cumulative curves) varied significantly among the species tested, Figs. I-1A and B. (The dry matter produced during winter months are excluded from the growth rate determination as they were under a plastic cover). As might be expected, the cool-season sods began faster growth than the warm-season grasses in the spring, then their growth rates, especially clover and orchardgrass slowed after midsummer. Buffalograss growth began sooner than bahiagrass in the spring, and both reached the peak growth in midsummer. In 1994 when the shade was provided, the growth rates were greatly reduced with orchardgrass and wheatgrass barely growing, clover growth could not be maintained. Bahiagrass better tolerated shade while buffalograss growth was greatly reduced.

The seasonal N concentrations of sods varied with species.(Table I-2) During 1992, buffalograss and bahiagrass had equally low N concentrations (14 g $kg^{-1}$), and the concentrations in buffalograss increased somewhat with season. Orchardgrass and wheatgrass had significantly higher N concentrations than the two warm season sods, except in the first harvest in April. Clover had the highest N concentration and it increased with season. The season average N concentration for the warm season species was 15 g $kg^{-1}$ and 21 to 23 g $kg^{-1}$ for the cool season (Table I-2). During 1994, the N concentrations were not greatly different, as expected.

The seasonal N uptake rates (the slope of the cumulative uptake curves) were similar to the growth rates in the spring (Figs. I-2 & B). This means that the N uptake by the cool season species exceeded that of the warm season species in the spring. The difference in N uptake rates between the warm season and the cool season species became smaller toward the mid-summer, as the growth rates of the warm season grasses have increased and the N concentration in the cool season species generally increased with season. After mid-summer, N uptake rates of clover and orchardgrass declined sharply with a rapid reduction in growth. During 1994 season, the cumulative N content of the clippings peaked around the first of August meaning that the net increase of grass production was low. This reduction was probably due to shading.

The annual N uptake (Table I-2) was the largest with buffalograss, followed by bahiagrass and wheatgrass, then by the two cool season species in 1993. This approximate trend was carried into 1994. During the 1992 season, the N uptake of the sods was less than the applied N fertilizer. During 1993, however, the N uptake approached that applied in the year. This high rate may be explained by the uptake of the carry-over N from the 1992 season, and in part by recycling of N as the harvested sod clippings were returned back to the lysimeters. During 1994, the N uptake and equilibrium tended towards release of N applied in previous fertilizations. The total amount of N collected in the clippings was 66% for bahiagrass, 34% for buffalograss, 16% for orchardgrass, 11% for wheatgrass, and none for clover. Shade has reversed and depressed N absorption potentials for surface sods.

b. Drainage and $NO_3$ Leaching

The depth of drainage, the annual average leaching fraction, the annual weighted mean concentration of $NO_3$ in the drainage water, and the quantities of N leached are summarized for each of the three growing seasons in Table I-3. Note that the drainage collection in 1992 began in September when clover was planted. The leaching fraction during 1992 season varied considerably, mainly because of large differences in sod growth rates during the year of establishment. During 1993 and 1994, the leaching fractions of sodded treatments were fairly close to each other. The leaching fractions in 1994 were higher than in 1993. The growth of grasses was less vigorous using less of the applied water.

The annual mean concentration of $NO_3$-N in drainage water varied significantly among the treatments (Table I-3). The concentration of $NO_3$-N in drainage water without sod averaged 25 mg $L^{-1}$ in Gila loam and 31 mg $L^{-1}$ in Bluepoint loamy sand in 1993 and similar values in 1994. Sodding with the warm season grass and wheatgrass reduced $NO_3$ leaching losses below 10 mg N $L^{-1}$ in 1993. The leaching losses of N from orchardgrass and clover plots were significantly higher than those from the warm season grasses (Table I-3). The leachate $NO_3$ concentrations greatly increased in 1994. Apparently nitrogen immobilized in plant tissue of 1992 and 1993 became available in 1994. Concentrations in 1994 approached 75 mg $NO_3$-N $L^{-1}$ with only the bahiagrass below 20.

The cumulative quantities of $NO_3$-N leached over the growing seasons are plotted against the cumulative drainage in Fig. I-3A & B and Table I-3. The rates of N leaching losses were reduced significantly with sodding in 1993. The cool season sods provided the lowest rate of N leaching during the early season, but the losses from orchard grass and clover have increased toward the end of the season. The warm season species exhibited N leaching loss rates higher than the cool season species during the early season, and lower rates toward the end of the growing season.

The N leaching losses from Gila sandy loam and Bluepoint loamy sand without sod amounted to 18 and 28% of the applied N in 1993 and 63 and 25% in 1994. Sodding reduced N leaching losses to as low as 3% of the applied in 1993, and 16% (bahiagrass) of the applied N in 1994 (Table I-3).

c. Water use and Soil Water Depletion Patterns

Annual water use data (evapotranspiration losses) are shown in Table I-4. Evapotranspiration losses of sodded treatments were 48 to 73% greater than those having no sod in 1993. The differences in losses among the treatments with different sods were comparatively small, 17% in 1993 and 40% in 1994. In 1994 the largest evapotranspiration loss was with the bare soils, especially with the Gila soil. Citrus without sod, even with shading, had grown to a size that produced nearly twice the evapotranspiration of any sod, except the wheatgrass.

Evapotranspiration losses (ET) from the sodded lysimeters include the transpiration losses from citrus trees, which had leaf areas less than 0.2 $m^2$ $m^{-2}$ in 1993 and the largest at 21 $m^2$ $m^{-2}$ in 1994 (Table I-5), which is the cumulative area divided by 5, the number of harvests. Thus, in 1993 the large portion of the ET observed in sodded treatments might be accounted for by the transpiration from sods, besides evaporation from the soil surface. In 1994, however, tree growth had reached a point in many treatments that ET from trees was approaching or exceeding that of the vegetative soil cover. ET losses from bare soils exceeded that in any sodded surface. Obviously shade had a depressive effect on sod as well as tree vigor. Tree vigor, however, appeared less impacted, particularly in the bare soil surface treatment.

The quantities of dry matter produced per unit quantities of water evapotranspired (water use efficiency, DEW) were generally higher with the warm season species than the cool season species (Table I-4). This appears to be related, in part, to the low water losses per leaf area.

Evapotranspiration rates over the growing seasons are shown in Fig. I-4, and they essentially followed the pattern of growth rates. In 1994, however, the trend for water loss (ET) was linear over time while N absorption plateaued after July.

d. Competition with Citrus Trees

Sodding reduced leaf production of citrus trees by many fold (Table I-5). In 1993, the reduction in growth was most severe when sodded with the warm season species with somewhat better growth when sodded with clover and orchardgrass. The imposition of shading greatly reduced the vigor of the sod in 1994. It appeared that even with a recently diminished, growing grass (e.g., clover) that tree growth did not recover. However, since growth started at levels established in 1993, the relative comparisons in 1994 represent the effects somewhat of the 1993 treatments. It appeared that the previous seasons competition between grass and tree took greater than one year to eliminate. Shading certainly reduced some of the expected increases of tree vigor with weakly growing surface sod. Tree growth on bare soil, however, was excellent.

The N concentration of citrus leaves measured in October 1993 was reduced severely when sodded with the warm season grasses, but were higher when sodded with the cool season species (Table I-5). However, the measurements made in June 1994 indicate lower N uptake contents even when sodded with the cool season grasses. At the end of the 1994 season the N concentrations of all treatment citrus trees were higher in sodded treatments than in the bare soil (except for the orchardgrass and clover treatments). It would appear that greater N absorption was occurring in some sodded treatments but absolute or relative growth of the citrus trees had not greatly increased.

## 4. Discussion

Nitrogen losses from soils can be reduced through sodding in young orchards. However, the soil surface vegetation has a depressive effect on tree growth as trees are poor competitors for N. Trees need the largest bulk of N early in the season as fruit or buds are developing. Grass is much more shallow rooted than trees so any fertilizer N must first transit a mat of surface vegetation with its absorptive potential. Cool season grasses like orchardgrass or wheatgrass where N absorption occurs earlier, have a serious impact on tree growth and development.

As an orchard increases in size and shade develops then the development of surface sod covers is depressed it would appear that control of $NO_3$ leaching depends on the vigorous growth of a grass, a problem if mature orchards are involved. In this respect, Bahiagrass seems to offer the best stable cover, because of its comparatively high shade tolerance. Buffalograss was found to be not shade-tolerant, and clovers could not sustain growth.

The results of this study also point out a strong need to develop sod management techniques to minimize the competition for N. The complete sodding of orchard floors, even with warm season grass species is likely to have a depressing effect on tree growth.

## 5. SUMMARY

Citrus tree growth was best in the bare soil treatments. The planting of a soil cover (sod) impacted the growth of citrus. The severity of the competition was related to the species of surface cover being grown. Cool season plants, orchardgrass and wheatgrass, had most depressing effect on citrus growth. This is due to an earlier N uptake by the cool season sods than occurred with the warm season species (bahiagrass, buffalograss). If the maximum N demand of tree and soil cover overlaps, then the N is preferentially absorbed by the grass rather than by the citrus trees.

The best citrus growth in the bare soil corresponds to maximum $NO_3$ leaching losses. Bare-soil nitrate concentrations are not controlled by sods so if tree N demand is not adequate to absorb all residual N, which it is not, much $NO_3$ is leached by percolating water. The 20% programmed leaching losses produced $NO_3$-N losses from bare soil of 18 to 28% losses of applied N. Nitrate nitrogen losses, in the presence of sod covers, dropped to as low as 1 to 3% of the applied N through N uptake (immobilization) by the sod species. Until the sod reaches its growth equilibrium, the grass will exert a strong competitive effect on tree growth by competition for soil N. Eventually the grass growth will reach an equilibrium at which point the net N losses to new grass growth should be zero. However, even when adequately supplied with N, regrowth in the spring or early summer requires much initial N, producing the increased N availability during later stages of growth. The constant clipping of sod covers recycles N allowing greater but later availability to the trees. However, timing of N absorption is critical to both tree and grass, delayed season N use will reduce nut and fruit production.

Growing sod under trees will increase water requirements. The decrease in other costs (disking, pesticide use, harvesting, etc.) has to exceed the cost of the extra water or producers will not be inclined to use vegetative covers. It was found that the cool season grasses had a higher water use per leaf area than did the warm season grasses. However, the higher transpiration loss (WL) corresponded to a reduced dry matter production per unit of water transpired (DMW). The growth of the sod cover increased water use by 40 to 60% with small trees. Under a mature orchard, shade intensity increases and should reduce consumptive use of water and nutrients by sods.

Small trees are easily deprived of the necessary N because grass grows much faster. A complicated and efficiently managed sod system will be necessary to control loss of $NO_3$ to the ground water and yet allow near optimum fruit and nut production.

Table I-1. Outline of the treatments imposed during 1992, 1993 and 1994 seasons.

| Soil Types | Types | Coverage % | Sodding 1992 1st | Sodding 1992 2nd | N applied[1] 1993 1st | 1993 2nd | 1993 3rd | 1994 1st | 1994 2nd | 1994 3rd | 1994 4th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | kg ha$^{-1}$ | | | | | | | | |
| Gila Sandy Loam | | | | | | | | | | | |
| | No sod | 0 | 53 | 83 | 150 | 150 | 53 | 53 | 53 | 53 | 53 |
| | Bahiagrass | 100 | 53 | 83 | 150 | 150 | 53 | 53 | 53 | 53 | 53 |
| | Buffalograss | 100 | 53 | 83 | 150 | 150 | 53 | 53 | 53 | 53 | 53 |
| | Clover | 100 | 53 | 83 | 150 | 150 | 53 | 53 | 53 | 53 | 53 |
| | Orchardgrass | 100 | 53 | 83 | 150 | 150 | 53 | 53 | 53 | 53 | 53 |
| | Wheatgrass | 100 | 53 | 83 | 150 | 150 | 53 | 53 | 53 | 53 | 53 |
| Bluepoint Loamy Sand | | | | | | | | | | | |
| | No sod | 0 | 53 | 83 | 150 | 150 | 53 | 53 | 53 | 53 | 53 |
| | Buffalograss | 100 | 53 | 83 | 150 | 150 | 53 | 53 | 53 | 53 | 53 |

[1] The date of N application for 1992 were 7/29 and 10/1; for 1993, 4/25, 6/7 and 9/9; and for 1994, 3/22, 6/24 7/28, and 8/23 respectively.

Table I-2. Annual dry clipping production, cumulative leaf area of fresh clippings, weighted annual mean N contents of dry clippings, and annual N uptake by sod species.

| Years Soils | Sod species | Dry clipping weight | Leaf area | N conc. | N Uptake content | N Recovery |
|---|---|---|---|---|---|---|
| | | Mg ha$^{-1}$ | m$^2$ m$^{-2}$ | g kg$^{-1}$ | kg ha$^{-1}$ | % |
| 1992 | | | | | | |
| Gila Sandy Loam | | | | | | |
| | Bahiagrass | 2.3 | 27 | 14.3 | 33 | 24 |
| | Buffalograss | 4.2 | 53 | 14.9 | 62 | 46 |
| | Clover | 2.3 | 46 | 21.0 | 48 | 35 |
| | Orchardgrass | 3.1 | 62 | 23.1 | 71 | 52 |
| | Wheatgrass | 5.4 | 46 | 20.4 | 110 | 81 |
| Bluepoint Loamy Sand | | | | | | |
| | Buffalograss | 5.4 | 67 | 16.3 | 88 | 65 |
| 1993 | | | | | | |
| Gila Sandy Loam | | | | | | |
| | Bahiagrass | 18.1 | 210 | 15.2 | 276 | 78 |
| | Buffalograss | 19.4 | 226 | 15.3 | 298 | 83 |
| | Clover | 7.8 | 158 | 21.2 | 184 | 52 |
| | Orchardgrass | 8.8 | 176 | 21.2 | 187 | 53 |
| | Wheatgrass | 13.9 | 118 | 22.9 | 269 | 76 |
| Bluepoint Loamy Sand | | | | | | |
| | Buffalograss | 12.7 | 159 | 15.7 | 55 | |
| 1994 | | | | | | |
| Gila Sandy Loam | | | | | | |
| | Bahiagrass | 7.3 | 91 | 20.0 | 146 | 66 |
| | Buffalograss | 3.7 | 46 | 20.5 | 76 | 34 |
| | Clover | 0.06 | 1 | - | - | 0 |
| | Orchardgrass | 1.3 | 16 | 27.7 | 36 | 16 |
| | Wheatgrass | 1.3 | 16 | 19.2 | 25 | 11 |
| Bluepoint loamy sand | | | | | | |
| | Buffalograss | 3.5 | 44 | 21.4 | 75 | 34 |

Table I-3. Annual quantities of drainage, the annual leaching fraction, the weighted mean $NO_3$-N concentrations in the drainage water and $NO_3$-N leached.

| Years Soils | Sod Types | Drainage depth | Leaching fraction | $NO_3$-N Conc. weighted | $NO_3$-N leached mass | $NO_3$-N leached % applied |
|---|---|---|---|---|---|---|
| | | cm | % | mg $L^{-1}$ | kg $ha^{-1}$ | % |
| 1992 (9/28-11/25) | | | | | | |
| Gila sandy loam | | | | | | |
| | No sod | 8 | 27 | 41 | 32 | 24 |
| | Bahiagrass | 5 | 18 | 26 | 13 | 10 |
| | Buffalograss | 5 | 21 | 10 | 6 | 4 |
| | Clover | 4 | 18 | 18 | 8 | 6 |
| | Orchardgrass | 3 | 11 | 22 | 8 | 6 |
| | Wheatgrass | 2 | 5 | 8 | 2 | 1 |
| Bluepoint loamy sand | | | | | | |
| | No sod | 9 | 33 | 38 | 35 | 26 |
| | Buffalograss | 6 | 16 | 14 | 8 | 6 |
| 1993 | | | | | | |
| Gila sandy loam | | | | | | |
| | No sod | 25 | 20 | 25 | 64 | 18 |
| | Bahiagrass | 19 | 11 | 11 | 21 | 6 |
| | Buffalograss | 17 | 11 | 9 | 17 | 5 |
| | Clover | 19 | 11 | 19 | 37 | 10 |
| | Orchardgrass | 16 | 9 | 18 | 30 | 8 |
| | Wheatgrass | 12 | 7 | 8 | 10 | 3 |
| Bluepoint loamy sand | | | | | | |
| | No sod | 29 | 29 | 31 | 100 | 28 |
| | Buffalograss | 27 | 20 | 9 | 25 | 7 |
| 1994 | | | | | | |
| Gila sandy loam | | | | | | |
| | No Sod | 24.8 | 19.6 | 60.3 | 139.0 | 63 |
| | Bahiagrass | 27.2 | 28.8 | 14.0 | 35.5 | 16 |
| | Buffalograss | 32.5 | 32.5 | 46.0 | 105.8 | 48 |
| | Clover | 28.7 | 29.6 | 74.6 | 198.7 | 90 |
| | Orchardgrass | 23.7 | 25.2 | 72.6 | 160.0 | 73 |
| | Wheatgrass | 21.5 | 20.6 | 44.8 | 89.4 | 41 |
| Bluepoint Loamy Sand | | | | | | |
| | No sod | 39.8 | 40.0 | 15.1 | 56.0 | 25 |
| | Buffalograss | 39.8 | 43.4 | 38.4 | 142.4 | 65 |

Table I-4. Annual irrigation depth, annual evaporative water losses (ET), dry matter produced per unit quantities of water evapotranspired (DEW), and the quantities of water evapotranspired per leaf area (WL).

| Years<br>Soils | Sod<br>Types | Irrig | ET | DEW | WL |
|---|---|---|---|---|---|
| | | cm | cm | kg $m^{-3}$ | L $m^{-2}$ |
| 1992 | | | | | |
| Gila sand loam | | | | | |
| | No sod | 29 | 21 | - | - |
| | Bahiagrass | 29 | 24 | - | - |
| | Buffalograss | 27 | 21 | - | - |
| | Clover | 31 | 27 | - | - |
| | Orchardgrass | 31 | 27 | - | - |
| | Wheatgrass | 37 | 35 | - | - |
| Bluepoint loamy sand | | | | | |
| | No sod | 27 | 18 | - | - |
| | Buffalograss | 35 | 29 | - | - |
| 1993 | | | | | |
| Gila sandy loam | | | | | |
| | No sod | 120 | 95 | - | - |
| | Bahiagrass | 163 | 144 | 1.25 | 6.9 |
| | Buffalograss | 158 | 141 | 1.33 | 6.5 |
| | Clover | 163 | 144 | 0.54 | 9.1 |
| | Orchardgrass | 180 | 164 | 0.54 | 9.3 |
| | Wheatgrass | 177 | 65 | 0.84 | 14.0 |
| Bluepoint loamy sand | | | | | |
| | No sod | 101 | 72 | - | - |
| | Buffalograss | 138 | 111 | 1.14 | 6.9 |
| 1994 | | | | | |
| Gila sandy loam | | | | | |
| | No sod | 102 | 77 | | |
| | Bahiagrass | 66 | 39 | | |
| | Buffalograss | 51 | 18 | | |
| | Clover | 70 | 41 | | |
| | Orchardgrass | 71 | 47 | | |
| | Wheatgrass | 80 | 59 | | |
| Bluepoint loamy sand | | | | | |
| | No sod | 61 | 22 | | |
| | Buffalograss | 52 | 12 | | |

Table I-5. Estimated leaf dry weights, estimated leaf area, measured N contents and estimated N uptake of citrus seedling trees.

| Years soils | Sod Types | Dry wt. leaf | Leaf area | Nitrogen concentration | N uptake content | N uptake portion |
|---|---|---|---|---|---|---|
| | | kg ha$^{-1}$ | m$^2$ m$^{-2}$ | g kg$^{-1}$ | kg ha$^{-1}$ | % |
| 1993 | | | | | | |
| Gila Sandy loam | | | | | | |
| | No sod | 13.7 | 0.93 | 24.3 | 0.33 | 0.09 |
| | Bahiagrass | 3.4 | 0.18 | 11.7 | 0.04 | 0.01 |
| | Buffalograss | 4.9 | 0.36 | 16.9 | 0.08 | 0.02 |
| | Clover | 7.8 | 0.56 | 22.1 | 0.17 | 0.05 |
| | Orchardgrass | 5.6 | 0.47 | 23.7 | 0.13 | 0.03 |
| | Wheatgrass | 4.7 | 0.40 | 23.7 | 0.11 | 0.03 |
| Bluepoint loamy sand | | | | | | |
| | No sod | 12.6 | 1.03 | 19.7 | 0.25 | 0.07 |
| | Buffalograss | 2.3 | 0.18 | 17.1 | 0.04 | 0.01 |
| 1994 | | | | | | |
| Gila Sandy loam | | | | | | |
| | Bare | 6,720 | 13.5 | 22.0 | 146.1 | 66.4 |
| | Bahiagrass | 1,573 | 4.8 | 25.5 | 39.2 | 17.9 |
| | Buffalograss | 1,517 | 5.7 | 24.8 | 37.8 | 17.2 |
| | Clover | 1,700 | 4.6 | 22.7 | 37.5 | 17.0 |
| | Orchardgrass | 544 | 2.0 | 21.8 | 10.2 | 4.6 |
| | Wheatgrass | 158 | 1.1 | 25.2 | 3.9 | 1.8 |
| Bluepoint loamy sand | Bare | 2122 | 21.4 | 22.5 | 47.9 | 21.8 |
| | Buffalograss | 707 | 6.7 | 25.3 | 17.9 | 8.1 |

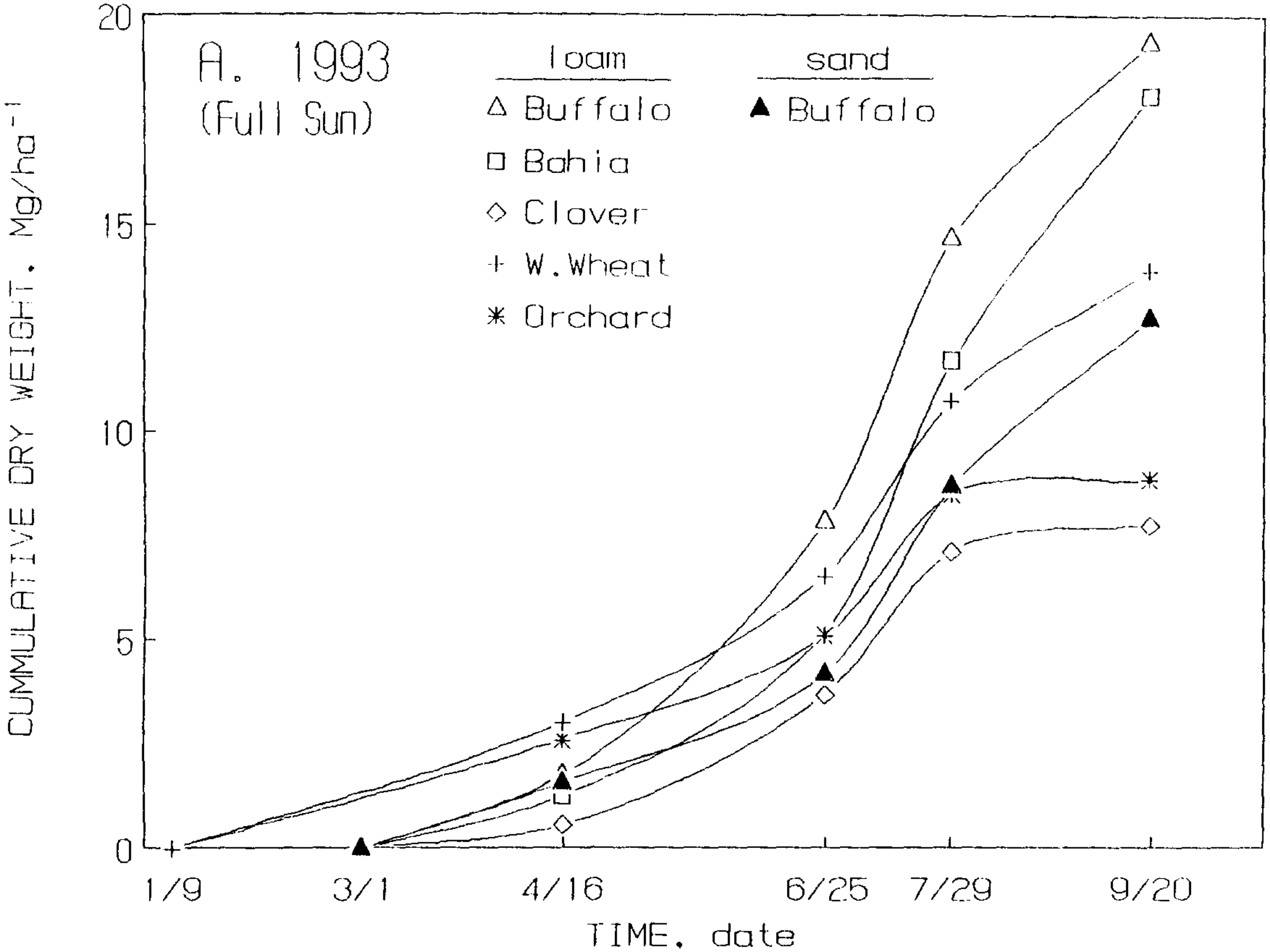
[1] The first and the second samplings of citrus leaves were made on July 1, 1993 and September 23, 1994.

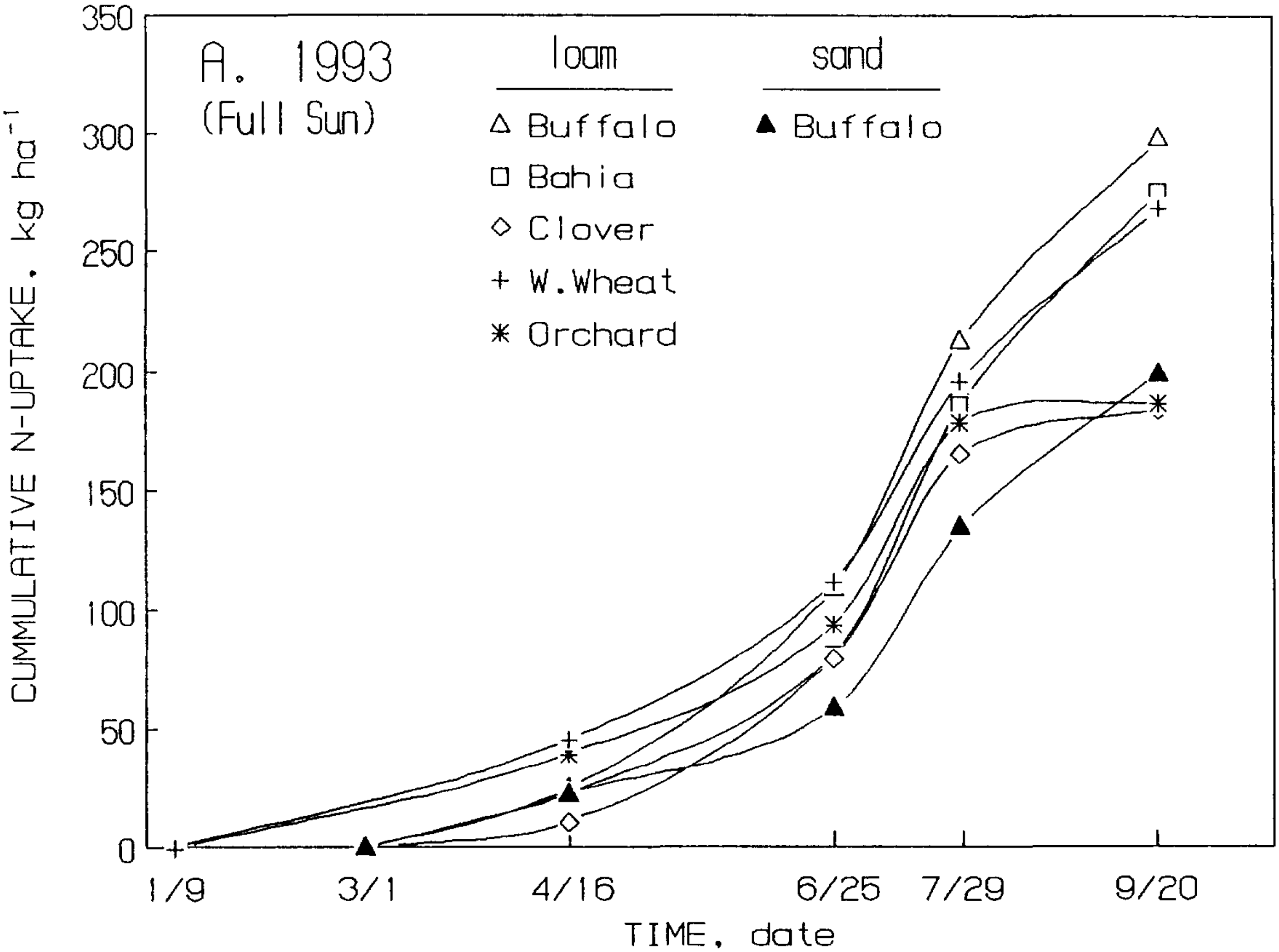
Fig. I-1 Cumulative clipping weight of five sod species grown in lysimeters in 1993 (Fig. 1A) and in 1994 (Fig 1B).

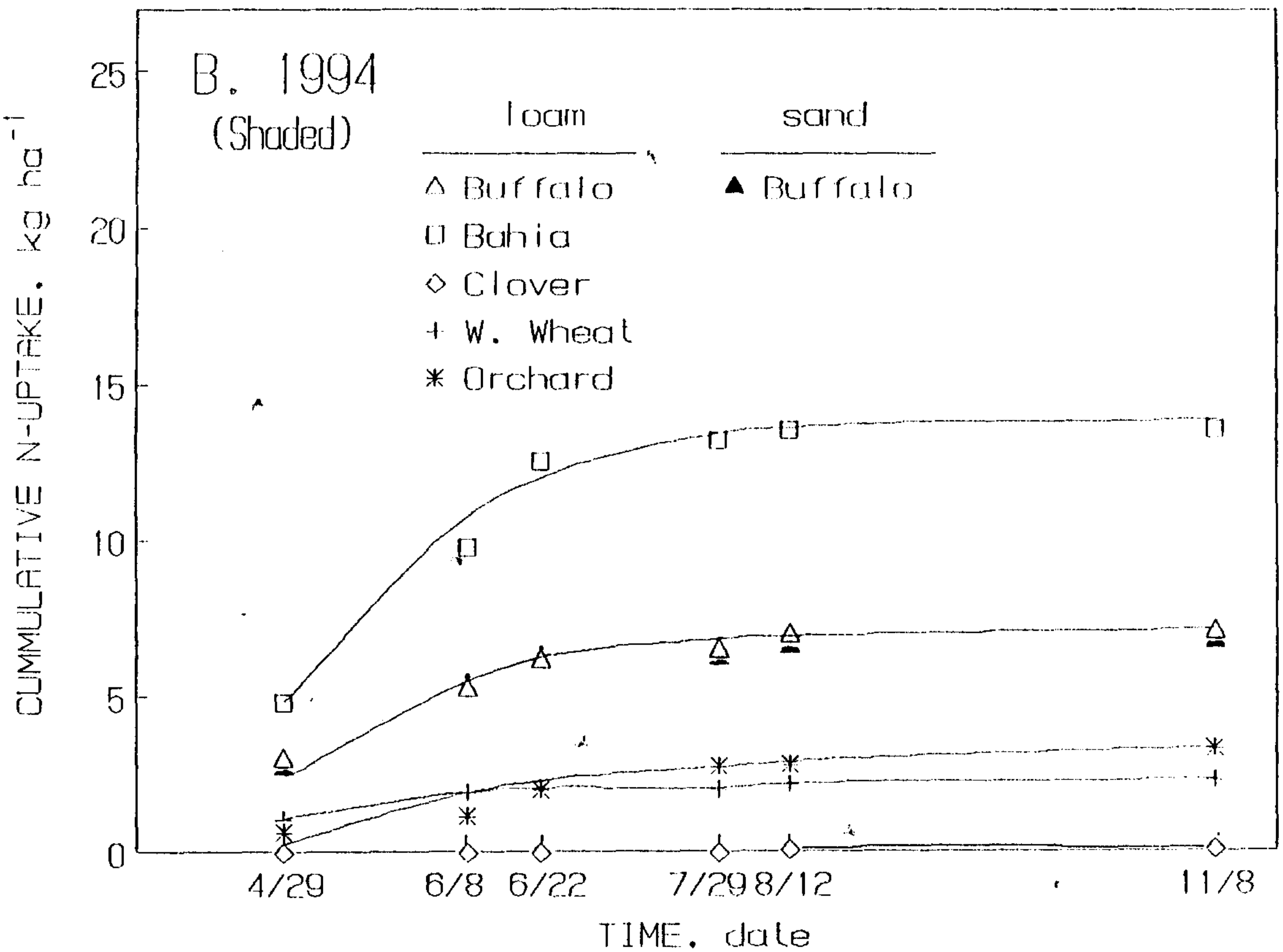
Fig. I-2 Cumulative nitrogen (N) uptake by five sod species over the growing season in 1993 (Fig. 2A) and in 1994 (Fig. 2B).

Fig. I-3 Cumulative N leaching losses as related to cumulative drainage in 1993 (Fig. 3A) and in 1994 (Fig. 3B).

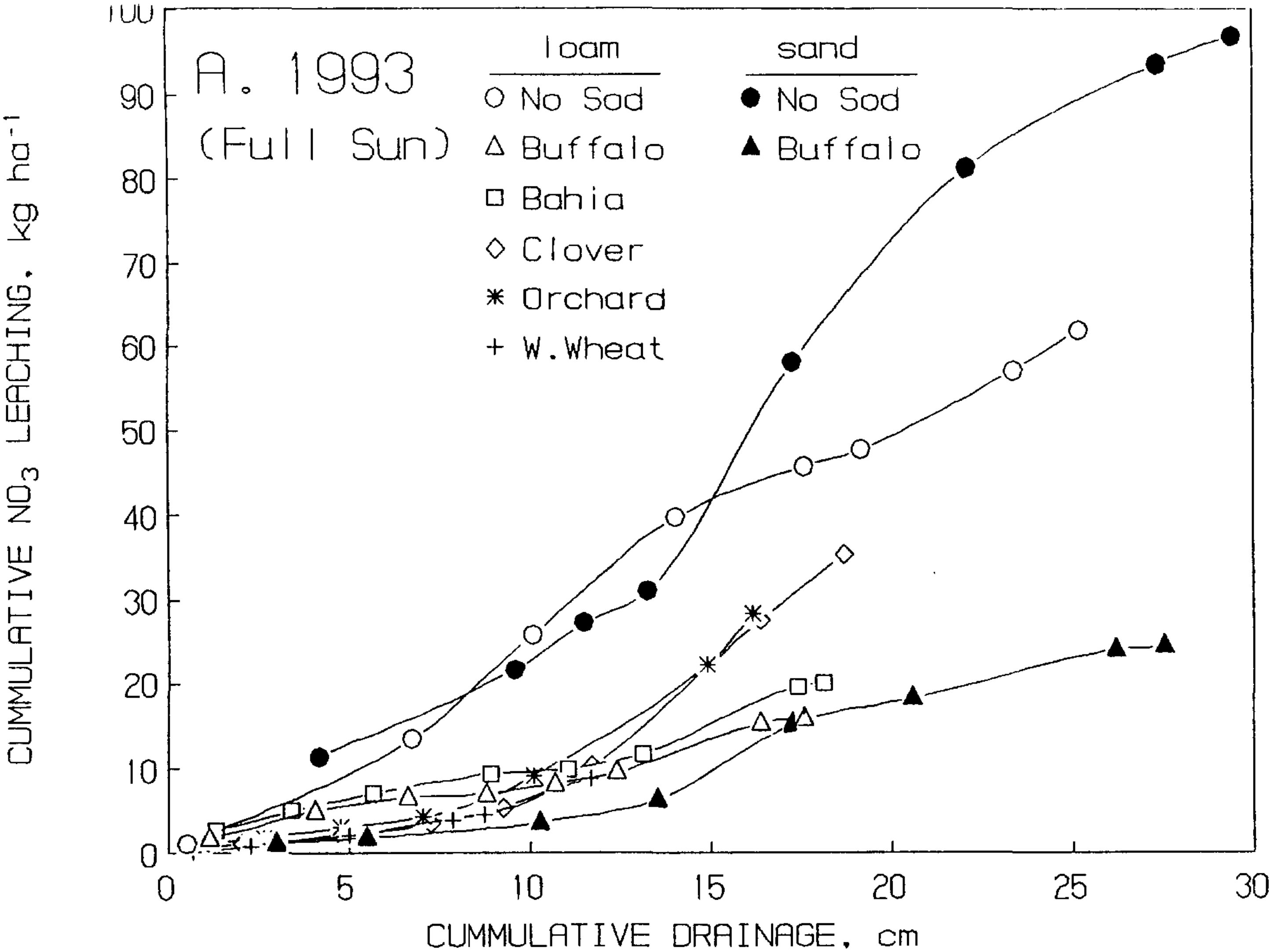
Fig. I-4 Cumulative water use of sods and trees in 1993 (Fig 4A) and in 1994 (Fig. 4B).


A. 1993
(Full Sun)
loam
sand
Buffalo
Bahia
Clover
W.Wheat
Orchard
Buffalo
CUMMULATIVE DRY WEIGHT, Mg/ha⁻¹
20
15
10
5
0
1/9
3/1
4/16
6/25
7/29
9/20
TIME, date

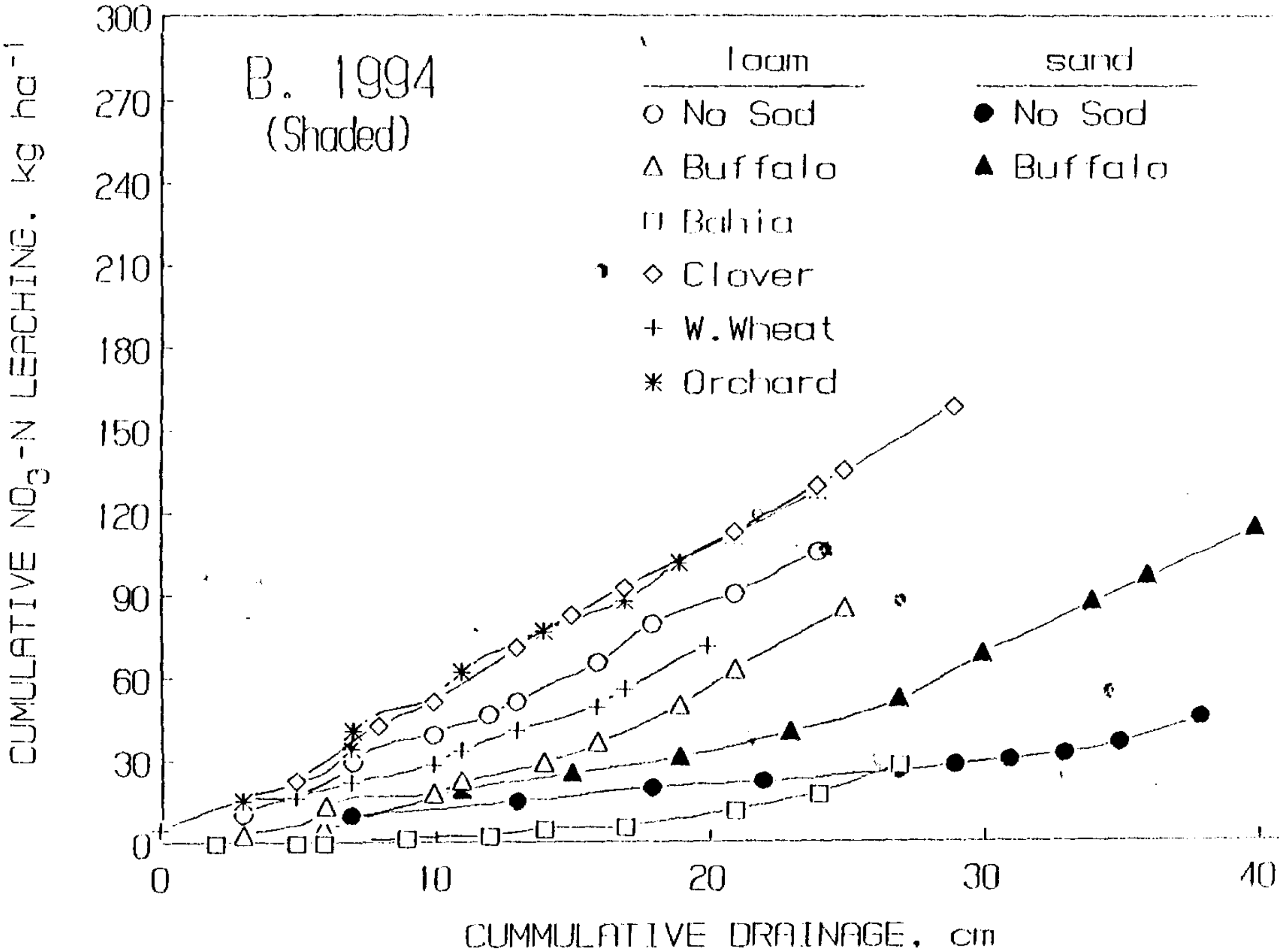

A. 1993
(Full Sun)
loam
sand
Buffalo
Bahia
Clover
W.Wheat
Orchard
Buffalo
CUMMULATIVE N-UPTAKE, kg ha-1
TIME, date
0
50
100
150
200
250
300
350
1/9
3/1
4/16
6/25
7/29
9/20

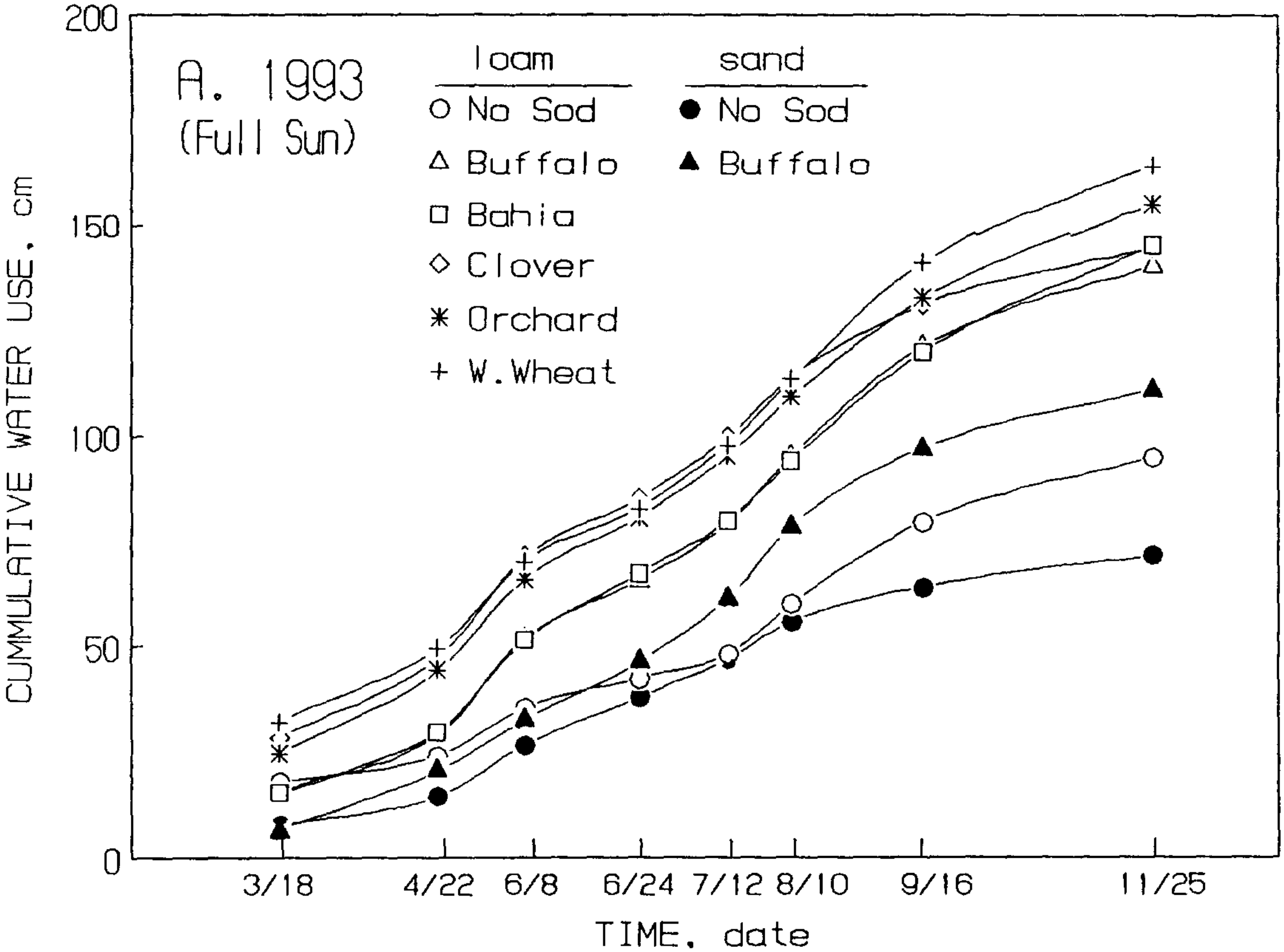


B. 1994
(Shaded)
loam
sand
Buffalo
Bahia
Clover
W. Wheat
Orchard
Buffalo
CUMMULATIVE N-UPTAKE, kg ha$^{-1}$
0
5
10
15
20
25
4/29
6/8
6/22
7/29
8/12
11/8
TIME, date

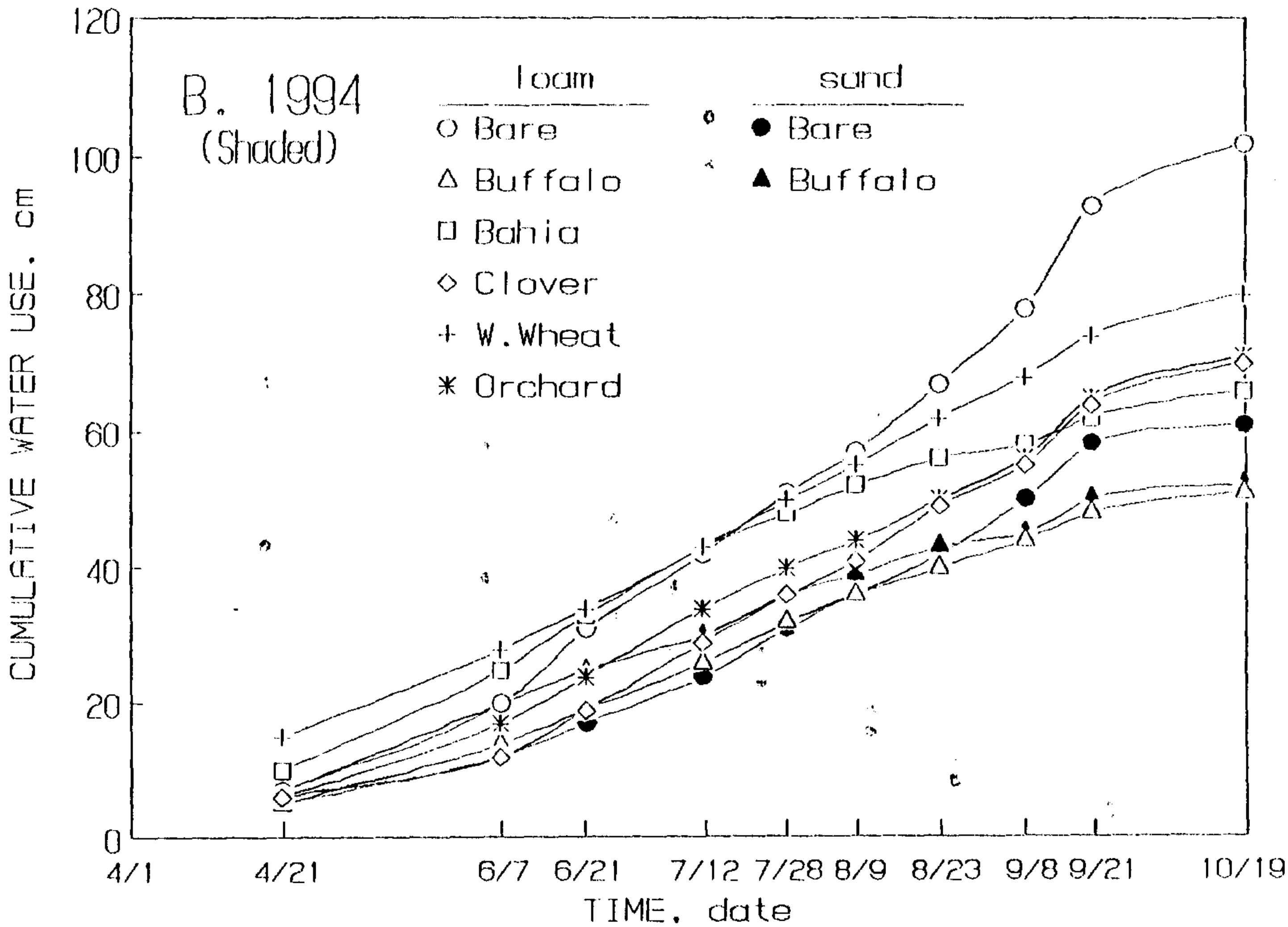


A. 1993
(Full Sun)
loam
sand
No Sod
Buffalo
Bahia
Clover
Orchard
W.Wheat
No Sod
Buffalo
CUMMULATIVE NO3 LEACHING, kg ha-1
CUMMULATIVE DRAINAGE, cm
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30


B. 1994
(Shaded)
loam
sand
No Sod
Buffalo
Bahia
Clover
W.Wheat
Orchard
No Sod
Buffalo
CUMULATIVE NO3-N LEACHING, kg ha-1
CUMMULATIVE DRAINAGE, cm
0
30
60
90
120
150
180
210
240
270
300
0
10
20
30
40



A. 1993
(Full Sun)
loam
sand
No Sod
No Sod
Buffalo
Buffalo
Bahia
Clover
Orchard
W.Wheat
CUMMULATIVE WATER USE, cm
200
150
100
50
0
3/18
4/22
6/8
6/24
7/12
8/10
9/16
11/25
TIME, date


B. 1994
(Shaded)
loam
sand
○ Bare
△ Buffalo
□ Bahia
◇ Clover
+ W.Wheat
✳ Orchard
● Bare
▲ Buffalo
CUMULATIVE WATER USE, cm
0
20
40
60
80
100
120
4/1
4/21
6/7
6/21
7/12
7/28
8/9
8/23
9/8
9/21
10/19
TIME, date

# II. EFFECTS OF SODDING AND SLOPING ON WATER AND NITROGEN BALANCE, COMPETITION AND DRAINAGE WATER QUALITY

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## 1. Introduction

The study reported in Section I (under Task I) indicates that sodding can be effective in reducing $NO_3$ leaching losses, but also increases water use and competition for nitrogen (N). The competition for N was so severe as to reduce leaf mass of citrus seedlings by many fold, and was largely induced for by the increase in N immobilization associated with N uptake by sod covers. These results as well as other reports outlined in the General Introduction indicate a need to develop ways to control competition and water use.

One of the ways to reduce competition for N is to select sod species of which peak N demands do not excessively overlap with those of tree crops. This means that in the case of deciduous trees such as pistachios, warm season grass species may be preferred over cool season species, since high N demands of deciduous trees come in the spring, while the N demands of warm season sod species come later in the season. Planting of cool season sods near the trees may impose competition to the trees in the spring when the trees require the most N. One of the objectives of this study was to test this hypothesis, using pistachio seedling trees as a test case.

Another method of reducing N competition and water requirements is to change sod management practices. Partial sodding which provides a buffer zone between the trees and sodded strips is, for example, a technique commonly used to reduce competition (e.g., Layne and Tan, 1988; Walker and Glenn, 1989). Another potential method is to apply increasing amounts of N and water toward the trees. However, both of these methods can reduce the effectiveness of reducing $NO_3$ leaching losses. Mulching of the buffer zone with clippings from the sodded strips may be another option which may reduce competition and water requirements. The second objective of this study was to evaluate the effectiveness of these sod management techniques on reducing competition and water requirements, while maintaining a control over $NO_3$ leaching losses.

## 2. Materials and Methods

An outdoor experiments using a large lysimeter assembly was conducted during 1992 through 1994 at El Paso, Texas. The lysimeter assembly consisted of 24 concrete compartments measuring 1.42 x 2.06 m and 1.0 m deep, each equipped with a drain port to collect leachate, and several neutron probe access tubes for soil moisture measurements. The lysimeter compartments contained Hueco sandy loam (coarse loamy, calcareous Typic Calciorthid) to a depth of 0.9 m. The soil was placed in the lysimeters 5 years prior to the present experiment, and was leached with local tap water until salinity of the drainage water was lowered below 1.5 dS $m^{-1}$. The water holding capacity after the completion of drainage was 17, 20, and 29 L $m^{-3}$ at three equally divided layers; 0-30, 30-60 and 60-90 cm, respectively. The source of irrigation water was local tap water having salinity of 700 mg $L^{-1}$, the sodium adsorption ratio of 4, and a pH of 8.3.

1992-1993 Experiments

Pistachio seedlings trees (P. Atlantica, 3 year old, about 0.3m in height) were planted in March along the edge of the lysimeter compartments, 2 seedlings per compartment with a tree spacing of 0.7 m in row, 0.2 m away from the compartment wall. Since the lysimeter compartments were arranged in 2 rows, seedling trees planted along the opposite side of the compartment edges provided a total of 2 tree rows with a spacing of 3.8m (Fig. II-1).

In May, 92, the surface of the soil in 12 out of 24 lysimeter containers was leveled to a zero slope, and the remaining 12 to provide a 1.8% slope (3.8 cm over 206 cm). This was followed by a preplant broadcast application of ammonium sulfate (50 kg N $ha^{-1}$) and triple super-phosphate (50 kg P $kg^{-1}$). Buffalograss (Buchloe dactyloides) was seeded in May in half of the ground surface away from the tree rows (Fig. II-1). Both the fertilizers and seed were raked in, and irrigated. In September, additional species; white clover (Trifolium repens) and orchardgrass (Dactylis glomeratea) were seeded in the area between the buffalograss strip and the tree rows to provide two additional treatments. The layout of the experiment was arranged in a split plot design; the slope factor as the main plots, and the sodding factor as subplots, each replicated three times. The last irrigation for 1992 was made on October 19.

The above set of the treatments was maintained throughout the 1993 growing season which started on March 15 with a broadcast application of 100 kg N $ha^{-1}$ as ammonium sulfate, followed by the first irrigation (Table II-1). The second N application was made on May 15 at 150 kg N $ha^{-1}$; the last irrigation for 1993 was made on October 4.

Irrigation water was applied when the soil moisture storage measured with a neutron probe was depleted in the range of 37 to 47% of the storage observed upon the cessation of the drainage in an amount to obtain a target leaching fraction of 10%. The actual quantities of water applied, drained and the leaching fractions attained are shown in Table II-2. The depths of water application ranged from 9 to 10 cm per application, and was delivered by a pump to fill the compartment in 3 to 5 min. Ponded water had infiltrated in 10 to 20 min in all the treatments.

The cover vegetation was mowed once in Aug. 1992, 2 times (June 10 and August 24) in 1993, to approximately 4 cm above the ground. The clipped plants were dried at 60C, weighed, and subsamples were analyzed for N contents after acid digestion. Pistachio seedling trees were evaluated for tree trunk growth in March and October. All the leaves were stripped off in October, dried at 60C, and dry weights and leaf N concentration determined as above.

1994 Experiment

The treatments were somewhat modified for the 1994 season. First, all the sections planted with orchardgrass were dug out, and the dry sod as well as the clippings from adjacent buffalograss strips were used as mulch in the area where orchardgrass was once grown. These dry sods were chopped and lightly incorporated into the soil so as to avoid clipping floating in the irrigation water. (Although this treatment is referred to as mulch, it can also be considered as a killed-sod treatment). The second modification consisted of banded application of N in an area between the buffalograss strips and the tree rows in the sloped treatments, while the broadcast application was maintained in the flat surface treatments.

The first irrigation was deliberately delayed until April 1 to suppress the growth of clover and the second irrigation was reduced by 20% so as to allow no drainage. The second fertilization was made on May 15 in the same manner as the first application. Additional neutron probe access tubes were placed to measure soil water depletion as a function of distances from the tree trunk as well as the depth of the soils. Other experimental procedures followed those used for 1992-1993.

## 3. Results

### a. Water and Salt Balance

The quantities of irrigation water applied in 1993 ranged from 90 to 110 cm, and those in 1994, 170 to 230 cm (Table II-2). The quantities of water drained ranged from 4 to 6 cm in 1993, and 9 to 12 cm in 1994, yielding the leaching fractions of 5 to 7%. (These leaching fractions are smaller than those commonly obtained under surface methods, but are within the range that may be obtained with sprinkler irrigation).

The salt concentration of drainage water ranged from 4 to 6 g $L^{-1}$ in 1993, irrespective of slopped or nonslopped treatments (Table II-3). In 1994, salinity of drainage water from the slopped treatment was somewhat lower, thus resulting in lesser quantities of salt leaching. This may suggest that soil salinity in the ridge portion of the slopped treatments might have had higher salt levels.

The leaching fractions obtained were 5 to 7% as noted earlier. If the salt balance is at steady-state, salinity of drainage water should have been in the range of 10 to 14 g $L^{-1}$ (assuming no salt precipitation). Since the actual measured salinity ranged from 4 to 6 g $L^{-1}$, the salt balance was probably not at steady-state. If the observed levels of salinity are to be maintained, the leaching fraction must be increased from the experimental levels to a range of 11 to 17%. This will increase the water requirements by about 10%. Salt leaching data also show that sodding did not increase salt concentrations in drainage water. However, salinity of the drainage water from the slopped and mulched treatment was lower than that from all other treatment.

The seasonal water use, expressed in the cumulative depth, is shown in Fig. II-2A for 1993 and 2B for 1994, and the seasonal total water use in Table II-2. The water use in the completely sodded plots was larger by about 10% in 1993, whereas this trend reversed itself in 1994. As shown later, the size of pistachio seedling trees in nonsodded plots was considerably larger than sodded plots in 1994 (Table II-5), and this may account for this apparent discrepancy. In any case, the increase in water use associated with sodding appears to be comparatively small in relatively high frequency irrigation where evaporation from soil surfaces are substantial.

b. Sod Growth and N Uptake

The growth of buffalograss in 1993 was approximately equal throughout the treatments. In 1994, however, the growth of buffalograss was greater in the flat and N broadcast treatments than in the slopped and banded N treatment, except for the first cuttings in May (Table II-4). The low growth rates in the slopped and banded treatment can be attributed to the fact that the buffalograss strips did not receive direct N fertilization.

The growth of clover in 1993 began first in the slopped treatment, then in the flat treatment (Table II-4). In 1994, the growth of clover was curtailed partly because of the deliberate delay in the first irrigation and partly because of the invasion of buffalograss. The growth of orchardgrass was better in the slopped treatment than in the flat treatment, presumably because of greater water application in the section where these cool season grasses had been grown.

The nitrogen concentrations of buffalograss started at 15 g $kg^{-1}$ (on the basis of dry weight) and decreased to 9 g $kg^{-1}$ in 1993 and were as low as 6 g $kg^{-1}$ at the end of the 1994 season (Table II-4). The nitrogen concentration in clover started at 35 to 36 g $kg^{-1}$, which then decreased to as low as 14 g $kg^{-1}$ at the end of the 1994 season. The nitrogen concentration of orchardgrass was closer to that of clover than that of buffalograss.

The uptake of nitrogen into the clipped portion of the sods was comparatively small, accounting for only a few percentages of the N applied in each year. The total clipping of buffalograss in 1994 reached 1000 kg/$ha^{-1}$ (or close to 2000 kg/ha on the basis of actual sodded area), and the corresponding N uptake into the clipping amounted to 11.6 kg $ha^{-1}$ or 5.8% of the N applied in the year. This, however, ignores the unclipped sods plus the below ground biomass which are probably larger in proportion.

c. Pistachio Growth and N Uptake

During the 1992 season, there was no significant effect of buffalograss sods (covering 50% of the ground area) on growth of pistachio seedling trees. However, recall that buffalograss was seeded in May and did not fully establish until the growth of pistachio seedlings had nearly completed for the year. Besides, the roots of pistachio seedling trees must have been confined as the seedling trees had just been planted in the spring.

During the 1993 season, tree growth was curtailed somewhat by partial sodding with buffalograss and was reduced by almost 50% by the complete sodding involving buffalograss and clover or orchardgrass (Table II-5). In addition, trees in these treatments have exhibited leaf yellowing and low N concentrations in leaf samples collected in May (Table II-5). The yellow leaves persisted for another month, even after the second N fertilization using 150 kg/ha.

During 1994, the rate of tree trunk growth has slowed to a typical value of 70 to 100% per year. The complete sodding as well as the sodding plus mulch treatment have deterred tree growth, especially when the N fertilizer was broadcast. The rate of tree trunk size increase was somewhat greater under the slopped and banded N application. Leaf weights per tree were still largest in nonsodded plots, as the tree sizes (which is cumulative) were still larger in the nonsodded plots.

Shoot growth measured during the spring to early summer of 1994 is shown in Fig. II-3. Shoot growth from the nonsodded treatments proceeded at a fast rate in the early spring, and this may reflect the high vigor of these trees. Shoot growth of sodded plots under the banded N application accelerated after the second application on May 15, except for the mulched treatment.

Nitrogen concentrations in pistachio leaf samples collected in May of 1993 decreased with increased sodding area. However, in the 1994 season, sodding induced insignificant reductions in leaf N concentrations (Table II-5). Banded N application did not significantly increase N concentrations, except in the buffalo/clover treatment. When measured at the end of the 1993 season, N concentrations of pistachio leaves were still lower in sodded plots, but were not significantly different among the treatments in 1994. The N taken up by pistachio leaves amounted to only 3 to 11% of the N applied in 1993 and 8 to 17% in 1994.

d. Nitrogen Leaching and Balance

The concentration of $NO_3$ in drainage water in 1992 increased from trace to 5 to 7 mg $L^{-1}$ after the first preplant N fertilization in May (Fig. II-4A). The concentration has remained essentially constant, then sharply increased in the last two irrigations following the 2nd fertilization (used to establish the cool season grasses). However, the presence of the buffalograss strip has lowered the $NO_3$ concentration in the drainage water. The $NO_3$ leached by the end of the season amounted to about 10% of the applied when no sod was present, and less than 5% when sodded with buffalograss (covering 50% of the lysimeter surface).

The concentrations of $NO_3$ in drainage water in 1993 began with the elevated concentrations in no sod treatments due to the carry-over from the 1992 season (Fig. II-4B). The concentration increased sharply in the drainage from the third irrigation following the first fertilization in nonsodded treatments, and reached as high as 250 mg $L^{-1}$. The $NO_3$ concentration in drainage water from the complete sodding remained low, especially under the broadcast application. However, there were some indications of N release from the sodded plots toward the end of the season.

The concentrations of $NO_3$ in drainage water, measured in 1994 in the flat and broadcast treatments, were similar in pattern to that observed in 1993, except that the concentrations in drainage water from the sodded plots were elevated (Fig. II-4C). The second $NO_3$ peak appeared in the 6th irrigation following the 2nd fertilization made prior to the 5th irrigation. The peak concentration reached 150 mg $L^{-1}$, which was lower than the peak concentration of 250 mg $L^{-1}$ observed in the 1993 season. (Note that the N application rate in the 2nd application was at 100 kg N $ha^{-1}$ in 1994, instead of 150 kg N $ha^{-1}$ used in 1993). The concentration of $NO_3$ then declined sharply, except in the mulched treatment which provided an additional small peak toward the end of the season.

The concentration of $NO_3$ in drainage water from the treatments using the banded application increased sharply in the 3rd irrigation, one irrigation sooner as compared to the case of the broadcast application. The second peak appeared in the 6th irrigation, (which is the same as the broadcast cases), then the concentrations decreased similarly to the broadcast cases, except in the banded treatment where $NO_3$ concentrations declined at a faster rate.

The quantities of N leached amounted to 23% from nonsodded plots (both flat and slopped) in 1993, and 22 to 31% in 1994 with a greater loss from the slopped and banded treatment. Sodding reduced leaching losses, especially in 1993, but its effect has reduced in 1994 (Table II-6).

In terms of the overall nitrogen balance, the leaching losses from nonsodded plots amounted to 23% in 1993, and 22 to 31% in 1994 (Table II-7). The uptake into pistachio leaves amounted to 11% in 1993, and 15 to 17% in 1994. This left more than half of the applied N unaccounted, and some of which might have been immobilized to stems and roots of pistachios. Sodding had a major impact on reducing nitrogen leaching losses in 1992 and 1993, and to a lesser extent in 1994. However, the uptake of N by clipped portions of leaves accounted for less than 10% of the applied N. Larger quantities of N was probably immobilized to roots and unclipped portion of the sods, in addition to roots and stems of pistachio seedling trees.

e. Soil Water Distribution and Depletion

The soil water contents after irrigation averaged 0.17 mL $cm^{-3}$ at 23 cm, 0.20 mL $cm^{-3}$ at 46 cm, and 0.29 mL $cm^{-3}$ at 70 cm. There was no significant difference in soil water content distribution between the flat and the slopped treatments after irrigation when measured at the tree rows, the midpoint (1 m from the tree rows), and the furthest from the tree rows (Fig. II-5). Recall that the sandy loam soil was placed over the sand/gravel layer. Thus, the soil water right above the boundary must become near saturation in order to obtain any drainage. Thus, it is entirely possible to have the soil water content of 0.29 mL $cm^{-3}$ at a soil depth of 70 cm after irrigation, irrespective of land slope.

The soil water content before irrigation was also relatively consistent, averaging 0.08 mL $cm^{-3}$ at 23 cm, 0.10 mL $cm^{3}$ at 46 cm, and 0.15 mL $cm^{-3}$ at 70 cm, irrespective of land slope or the presence or absence of sods (Fig. II-5). This provided the soil water depletion of 0.09 mL $cm^{-3}$ at 23 cm, 0.10 mL $cm^{-3}$ at 46 cm, and 0.14 mL $cm^{-3}$ or the weighted average depletion of 9.4 cm per soil depth of 90 cm. The actual irrigation depths ranged from 9 to 10 cm per application. In the slopped treatments, the elevations of the soil surface was 3.8 cm lower near the tree rows as compared to the highest point away from the tree rows. If irrigation water had penetrated in proportion to the ponding depth, the irrigation depth at the highest point should have been 8.2 cm per application. This depth of water can penetrate to a depth of 77 cm, even if we take the elevated soil water storage toward the lysimeter bottom into consideration. Under such conditions, we would expect that the soil water distribution after irrigation under the slopped configuration would be similar to that under the flat ground surface.

## 4. DISCUSSION

One of the objectives of this study was to evaluate if sodding with cool season species may pose competition for N, because of the overlap with the N demand of deciduous trees in the spring and early summer. Severe competition for N was indeed observed in 1993 when pistachio seedling trees were grown with the combination of buffalograss and clover or orchardgrass, but not buffalograss alone (Table II-5). (These findings, however, cannot be solely attributed to the presence of the cool season grasses, because buffalograss alone occupied only half of the ground surface). The competition was lessened in 1994, presumably due to the reduced growth of clover (Table II-4) and possibly due to reduced N demands as indicated by the higher $NO_3$ concentrations in drainage water in 1994 as compared to 1993 (Table II-6). Even so, tree growth was suppressed in the buffalo-clover plot (Table II-5), and shoot growth was also curtailed (Fig. II-2), especially when N fertilizer was broadcast. Introduction of cool season grasses, including legumes is probably not acceptable.

Another objective of this study was to assess if the competition can be minimized by applying increasing quantities of water and nitrogen fertilizers toward the tree rows. Such conditions were achieved through ground slopping and banded fertilizer application. The effect of slopping on tree growth and tree N uptake was, however, minimal in 1992 and 1993 when N fertilizers were broadcast (Table II-5). In the buffalograss-clover sod plot, tree growth and N concentrations of pistachio leaves were somewhat lower in the slopped treatment, presumably due to increased competition as clovers in the slopped treatment grew better than in the non-slopped treatment in the spring to early summer (Table II-4). The lack of apparent benefits of slopped treatment is probably related to the similar soil water distribution pattern created by the condition of the lysimeter, as pointed out earlier. At the same time, it should be noted that stratified soils with high water tables are common feature in alluvial soils of the middle Rio Grande Basin.

Application of fertilizers in a band (or strip) along the tree row away from the sodded area enhanced shoot growth (Fig. II-2), deterred sod growth (Table II-4), and promoted N uptake and tree growth, especially in the buffalograss-clover plots (Table II-5). However, applied N was leached more readily (fig. II-4C) and resulted in greater N leaching losses (Table II-6). If the orchard management objective is to promote the rapid shoot growth (as often the case in young orchard), banded N application in the first application may proof more effective than broadcast applications. Band application of N in the subsequent applications may not provide any particular advantage, other than reducing sod growth.

An additional objective of this study was to evaluate the effect of mulch placed between trees and the sodded strip. When the N fertilizer was broadcast, this treatment provided tree growth, tree N uptake and N leaching characteristics similar to having live orchardgrass. Microbial immobilization of N is probably responsible. With depletion of orchardgrass residues, the system may approach to that of the partial sodding with buffalograss. When the N fertilizer was banded, the competition for N was reduced and resulted in improved tree growth, (Table II-5). The study of a longer duration is needed to assess the effect of mulching on the nitrogen balance.

The unaccounted portion of N amounted to a major portion, especially in 1993. There is no doubt that a considerable portion of the unaccounted N was immobilized to unclipped portions of the sods and grass roots, plus stems and roots of pistachio seedling trees. However, we cannot ignore a possibility of substantial quantity of microtrial immobilization as well as denitrification.

From the view of pollution of drainage water, high concentrations of $NO_3$ following fertilization raises a concern. Pecan growers in the middle Rio Grande commonly use the fertilization programs used for this experiment, mainly to force rapid shoot and tree growth in the spring months. In most orchards along the middle Rio Grande, the root zone of the trees rarely extend 60 cm, mainly due to high water tables. Water-run application of N at lower rates would help reduce $NO_3$ concentrations, but it is currently unknown if low N concentrations are sufficient to yield the desired shoot and tree growth of deciduous trees. A recent trend is to use high dosages of banded N fertilizers to stimulate tree growth, which seems to be the worst scenario as far as $NO_3$ leaching loses are concerned. Having sods, even if they are dead, seem to be desirable in reducing the peak $NO_3$ concentrations, but its effectiveness seems to decrease as the N demand of the ground vegetation is met. In essence, the role of ground cover vegetation seem to be limited to provide a N reservoir which acts as a pool for N, thus buffering the sharp fluctuation in N levels in soils associated with occasional high dosages of nitrogen fertilizers.

Future studies should focus on water-run application of N at low rates and the quantification of N balance, including denitrification. In spite of the high $NO_3$ concentrations observed in drainage water in this experiment, existing field data on $NO_3$ concentrations of open agricultural drains show low concentrations which cannot be accounted for by dilution alone. Denitrification as well as immobilization in drainage ditches (which are usually loaded with organic matter) are likely the process by which $NO_3$ concentrations are reduced. At the same time, we find high $NO_3$ concentrations in soil solution in clay soils. A field scale study is needed to understand the nitrogen balance. Meantime, partial sodding with warm season vegetation along with more frequent N applications at lower application rates may help reduce the peak $NO_3$ concentrations in drainage water.

## 5. SUMMARY

Pistachio seedling trees were grown in large outdoor lysimeters (1.4 X 2.06 m) for a period of 2 1/2 years under various floor management scenarios involving sodding, mainly to evaluate $NO_3$ leaching losses and sod/tree competition. During the year of tree and sod establishment, the floor management options included clean cultivation and partial sodding with buffalograss under the flat and the slopped (1.8%) ground surfaces. Nitrogen as ammonium sulfate was applied in May and September at a combined rate of 100 kg $ha^{-1}$. The partial sodding with buffalograss reduced $NO_3$ leaching losses from 11 to 5 or 6%, while presenting no adverse effects on growth of pistachio seedling trees.

During the 2nd growing season (1993), two cool season species (clover and orchardgrass planted in September 1992 between the buffalograss strip and the tree rows) were included as additional treatments. Nitrogen as ammonium sulfate was applied in March 15 and May 15 at a rate of 100 kg $ha^{-1}$, and 150 respectively. Partial sodding with buffalograss reduced $NO_3$ leaching from 23 to less than 11%, and the full sodding involving buffalograss and clover or orchardgrass lowered $NO_3$ leaching losses down to less than 6%. However, all sodded treatments, especially those involving clover and orchardgrass caused severe competition for N, especially in the spring when both cool season sods and pistachio seedling trees require the largest quantities of N. This led to a nearly 50% reduction in seedling tree growth as well as

nitrogen deficiency in pistachio. The reduction in $NO_3$ leaching losses appeared to have been induced by uptake of N by the sod. Slopping of the land caused no major difference in plant growth, but has increased $NO_3$ leaching somewhat. Sodding increased water use up to about 10%.

During the third growing season (1994), the orchardgrass planted between the buffalograss strips and the tree rows was removed and was converted to a mulching treatment using the clipping from buffalograss. In addition, the slopped plots received banded (or strip) application of ammonium sulfate along the tree rows, 100 kg $ha^{-1}$ in April 1 and 100 kg $ha^{-1}$ in May 15, while the flat plots have received the broadcast application at the same rate. The nitrate leaching losses in the broadcast treatment without sod were essentially the same as 1993, while they increased to 31% under the banded application. Partial sodding with buffalograss presented only a minor reduction in $NO_3$ leaching losses; 19 and 28% as compared to 22 and 31% from non-sod treatment under the flat and broadcast N application, and the sloped and banded N application, respectively. The complete sodding with buffalograss and clover, and the combination of buffalograss and mulch reduced $NO_3$ leaching to 15% under the flat and broadcast N application. However, there was no significant reduction in $NO_3$ leaching from the complete sodding with buffalograss and clover under the slopped and banded N application treatments. Sodding presented no major reduction in pistachio tree growth in 1994, except under the buffalograss and clover treatment which received broadcast N application. Banding of N fertilizers generally provided improved shoot growth in the early summer. Sodding as well as mulching (or killed sod) lowered the peak $NO_3$ concentrations in drainage water following the first application of N.

The studies reported here seem to indicate that sodding is effective in reducing $NO_3$ leaching losses while sods are actively growing and taking up nitrogen or the sod residues undergo decomposition. Once the N demand of sods is met, the use of ground cover vegetation for reducing $NO_3$ leaching losses seems to have a limitation, and the primary role seems to shift toward the increased storage of N in soils, which can help reduce the peak $NO_3$ concentrations in drainage water. Future study should focus on water-run application of N at lower rates and a field scale N balance analysis.

Table II-1. Outlines of the treatments imposed during 1992, 1993 and 1994 seasons.

| Years | Sodding: Types | Ground sodded | N application[1]: 1st | 2nd |
|---|---|---|---|---|
| | | % | kg N $ha^{-1}$ | |
| 1992 May-Aug | | | | |
| | Flat and sloped at 1.8% | | | |
| | No sod | 0 | 50 | 50 |
| | Buffalo | 50 | 50 | 50 |
| 1993 Sept - 1993 Oct | | | | |
| | Flat and sloped at 1.8% | | | |
| | No sod | 0 | 100 | 150 |
| | Buffalo | 50 | 100 | 150 |
| | Buffalo/clover | 50/50 | 100 | 150 |
| | Buffalo/orchard | 50/50 | 100 | 150 |
| 1994 March - Oct | | | | |
| | Flat and sloped at 1.8% and banded N Application[2] | | | |
| | No sod | 0 | 100 | 100 |
| | Buffalo | 50 | 100 | 100 |
| | Buffalo/clover | 50/50 | 100 | 100 |
| | Buffalo/mulch | 50/50 | 100 | 100 |

[1] The first N application in March, and the second application in May 15 in both 1993 and 1994.

[2] Banded N application consisted of the same quantity of N per lysimeter, but was applied only in the area between the buffalograss strips and the tree rows.

Table II-2. The quantities of water applied and drained, and the average leaching fraction during each growing seasons.

| | No. of irrig. | | Applied | | Drained | | Evapotranspired | | Leaching Fraction[1] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped |
| | | | cm | | cm | | cm | | % | |
| 1992 May - Oct. | | | | | | | | | | |
| No Sod | 7 | 7 | 46 | 44 | 6.8 | 6.0 | 37 | 36 | 14 | 13 |
| Buffalo | 7 | 7 | 50 | 51 | 6.2 | 6.3 | 44 | 45 | 12 | 12 |
| 1993 March - Oct. | | | | | | | | | | |
| No sod | 10 | 10 | 98 | 92 | 4.3 | 4.3 | 94 | 88 | 4 | 5 |
| Buffalo | 10 | 10 | 95 | 102 | 5.2 | 6.1 | 89 | 96 | 5 | 6 |
| Buffalo/Clover | 10 | 10 | 112 | 98 | 6.0 | 5.0 | 107 | 93 | 6 | 5 |
| Buffalo/Orchard | 10 | 10 | 101 | 113 | 6.4 | 6.5 | 95 | 106 | 6 | 6 |
| 1994 April - Oct. | | | | | | | | | | |
| No Sod | 14 | 14 | 224 | 235 | 9.0 | 12.1 | 206 | 223 | 4 | 5 |
| Buffalo | 14 | 14 | 185 | 187 | 9.2 | 9.3 | 176 | 178 | 5 | 5 |
| Buffalo/Clover | 14 | 14 | 185 | 170 | 9.0 | 9.6 | 176 | 161 | 5 | 5 |
| Buffalo/Mulch | 14 | 14 | 180 | 178 | 11.8 | 8.1 | 185 | 170 | 7 | 5 |

[1] Leaching fraction = drained/applied

Table II-3. The quantities of water drained, salt concentrations in drainage water and salt leaching losses.

| | Salt Input | | Drainage | | Salt concent | | Salt Leached | | Salt leaching percent | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped |
| | $g\ m^{-2}$ | | cm | | $g\ L^{-1}$ | | $g\ m^{-2}$ | | % | |
| 1992 | | | | | | | | | | |
| No sod | 324 | 310 | 6.8 | 6.0 | 1.5 | 1.7 | 102 | 102 | 31 | 33 |
| Buffalo | 352 | 359 | 6.2 | 6.3 | 1.7 | 1.7 | 105 | 107 | 30 | 30 |
| 1993 | | | | | | | | | | |
| No sod | 690 | 648 | 4.3 | 4.3 | 5.7 | 5.6 | 245 | 241 | 35 | 37 |
| Buffalo | 669 | 718 | 5.3 | 6.1 | 4.4 | 4.3 | 233 | 262 | 35 | 36 |
| Buffalo/Clover | 788 | 689 | 5.6 | 5.0 | 4.2 | 4.2 | 235 | 210 | 30 | 30 |
| Buffalo/Orchard | 711 | 796 | 6.1 | 6.3 | 4.9 | 4.9 | 299 | 309 | 42 | 39 |
| 1994 | | | | | | | | | | |
| No sod | 1577 | 1654 | 9.0 | 12.1 | 5.9 | 3.6 | 531 | 436 | 34 | 26 |
| Buffalo | 1302 | 1316 | 9.2 | 9.3 | 5.6 | 5.1 | 515 | 474 | 39 | 36 |
| Buffalo/Clover | 1302 | 1197 | 8.9 | 9.6 | 4.9 | 4.0 | 436 | 384 | 36 | 32 |
| Buffalo/Mulch | 1267 | 1253 | 11.8 | 8.1 | 5.1 | 2.8 | 602 | 228 | 47 | 18 |

Table II-4. Clipping dry weights, and nitrogen concentrations of the clippings and nitrogen uptake by the clippings.

| Clipping Date Sod | Top dry wt. Flat | Top dry wt. Sloped | N Concent. Flat | N Concent. Sloped | N uptake Flat | N uptake Sloped | N uptake[1] Flat | N uptake[1] Sloped |
|---|---|---|---|---|---|---|---|---|
| | kg ha$^{-1}$ | | kg$^{-1}$ | | kg ha$^{-1}$ | | % | |
| 1993 June 10 | | | | | | | | |
| Buffalo | 180/00 | 180/00 | 15/00 | 15/00 | 2.7/00 | 2.7/00 | 1.1/00 | 1.1/00 |
| Buffalo/Clover | 150/35 | 160/90 | 15/34 | 15/35 | 2.7/1.2 | 2.7/3.2 | 1.1/0.5 | 1.1/1.3 |
| Buffalo/Orchard | 150/80 | 160/120 | 14/29 | 14/27 | 2.5/2.3 | 2.5/3.2 | 1.0/0.9 | 1.0/1.3 |
| August 11 | | | | | | | | |
| Buffalo | 410/00 | 430/00 | 9/00 | 10/00 | 3.6/00 | 4.3/00 | 1.4/00 | 1.7/00 |
| Buffalo/Clover | 390/230 | 410/90 | 9/29 | 9/27 | 3.6/6.6 | 3.9/2.4 | 1.4/2.6 | 1.5/1.0 |
| Buffalo/Orchard | 400/16 | 410/70 | 10/12 | 9/13 | 4.0/1.9 | 3.9/0.9 | 1.6/0.8 | 1.5/0.4 |
| 1994 May 23 | | | | | | | | |
| Buffalo | 170/00 | 200/00 | 17/00 | 14/00 | 2.9/00 | 2.8/00 | 1.4/00 | 1.4/00 |
| Buffalo/Clover | 130/12 | 160/6 | 15/36 | 12/35 | 2.0/0.4 | 1.9/0.2 | 1.0/00 | 1.4/00 |
| Buffalo/Mulch | 140/00 | 170/00 | 15/00 | 12/00 | 2.1/00 | 2.0/00 | 2.1/00 | 1.0/00 |
| June 10 | | | | | | | | |
| Buffalo | 410/00 | 200/00 | 14/00 | 14/00 | 5.7/00 | 2.8/00 | 2.9/00 | 1.4/00 |
| Buffalo/Clover | 410/140 | 90/30 | 16/33 | 11/28 | 6.6/4.6 | 1.0/1.4 | 3.3/2.3 | 0.5/0.7 |
| Buffalo/Mulch | 340/00 | 95/00 | 15/00 | 11/00 | 5.1/00 | 1.0/00 | 2.5/00 | 0.5/00 |
| Aug. 27 | | | | | | | | |
| Buffalo | 430/00 | 320/00 | 7/00 | 8/00 | 3.0/00 | 2.6/00 | 1.5/00 | 1.3/00 |
| Buffalo/Clover | 670/.7 | 410/20 | 8/16 | 8/14 | 5.3/0.1 | 3.3/0.3 | 2.6/00 | 1.6/0.1 |
| Buffalo/Mulch | 690/00 | 450/00 | 6/00 | 7/00 | 4.1/00 | 3.2/00 | 2.0/00 | 1.6/00 |

[1] The percent of N applied for each year.

Table II-5. Trunk diameter, annual increases in trunk cross-section, dry leaf weights, leaf N concentration and leaf N uptake of pistachio seedling trees.

| | Trunk dia. | | Increase in C section | | Leaf wt. | | N concent. (May) | | N concent. (Oct) | | N uptake | | N uptake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped |
| | -------cm-------- | | %/year | | g/tree | | $g\ kg^{-1}$ | | $g\ kg^{-1}$ | | N g/tree | | % | |
| 1992 | | | | | | | | | | | | | | |
| No sod | 1.7 | 1.7 | | | | | | | | | | | | |
| Buffalo | 1.6 | 1.6 | | | | | | | | | | | | |
| 1993 | | | | | | | | | | | | | | |
| No Sod | 3.8a[1] | 3.8a[1] | 400a | 400a | 209a | 196a | 20a | 21a | 19a | 19a | 3.9a | 3.8a | 11 | 11 |
| Buffalo/ | 3.3b | 3.3b | 310b | 310b | 175b | 142b | 19a | 19a | 19a | 18a | 3.2b | 2.6b | 8 | 7 |
| Buffalo/Clover | 3.1b | 2.8b | 275b | 206b | 88c | 77c | 16b | 14b | 18a | 15b | 1.6c | 1.1c | 4 | 3 |
| Buffalo/Orchard | 3.0b | 3.0b | 252b | 252b | 83c | 91c | 15b | 15b | 17a | 17ab | 1.4c | 1.5c | 4 | 4 |
| 1994 | | | | | | | | | | | | | | |
| No sod | 5.0 | 5.1 | 73ab | 80a | 297a | 271a | 20a | 21a | 17a | 16ab | 5.0a | 4.3a | 17 | 15 |
| Buffalo | 4.6 | 4.7 | 94a | 102a | 232b | 253b | 20a | 20ab | 18a | 17a | 4.2b | 4.3a | 14 | 15 |
| Buffalo/Clover | 3.9 | 3.8 | 58b | 84a | 157c | 157c | 19a | 23a | 18a | 15b | 2.8c | 2.5b | 9 | 8 |
| Buffalo/mulch | 3.9 | 4.3 | 69b | 105a | 120c | 146c | 19a | 19a | 17a | 17a | 2.0c | 2.5b | 7 | 8 |

[1] Numbers in columns followed by the same letter are not significantly different at a 5% level.

able II-6. The quantities of water drained, N Concentrations in drainage water and nitrogen leaching losses.

| | Drainage | | N conc. | | N leaching | | N leaching | |
|---|---|---|---|---|---|---|---|---|
| | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped |
| | cm | | mg $L^{-1}$ | | kg $ha^{-1}$ | | % | |
| 992 | | | | | | | | |
| No sod | 6.8 | 6.0 | 16a | 15a | 11a | 9a | 11 | 9 |
| Buffalo | 6.2 | 6.3 | 6b | 9b | 3b | 6a | 3 | 6 |
| 993 | | | | | | | | |
| No sod | 4.3 | 4.3 | 136a | 133a | 59a | 57a | 23 | 23 |
| Buffalo | 5.3 | 6.1 | 19b | 45b | 10b | 28b | 4 | 11 |
| Buffalo/Clover | 5.6 | 5.0 | 7c | 5d | 4c | 2d | 2 | 1 |
| Buffalo/Orchard | 6.1 | 6.3 | 8c | 24c | 5c | 15c | 2 | 6 |
| 994 | | | | | | | | |
| No sod | 9.0 | 12.1 | 48a | 51b | 43a | 62a | 22 | 31 |
| Buffalo | 9.2 | 9.3 | 42ab | 59b | 38ab | 55b | 19 | 28 |
| Buffalo/Clover | 8.9 | 9.6 | 31b | 68a | 27b | 65a | 14 | 33 |
| Buffalo/Mulch | 11.8 | 8.1 | 26c | 54b | 31b | 44b | 15 | 22 |

Numbers followed by the same letters are not significantly different at a 5% level.

Table II-7. The quantities of nitrogen applied, taken into grass leaves, uptake into pistachio leaves, leached and the balance.

| | Nitrogen applied | Uptake sod leaf | | Uptake Pist. leaves | | Leached | | Balance | |
|---|---|---|---|---|---|---|---|---|---|
| | | Flat | Sloped | Flat | Sloped | Flat | Sloped | Flat | Sloped |
| | kg ha$^{-1}$ | | | ------------------- % ------------------- | | | | | |
| 1992 May - Oct. | | | | | | | | | |
| No Sod | 50 | - | - | - | - | 11 | 9 | - | - |
| Buffalo | 50 | - | - | - | - | 3 | 6 | - | - |
| 1993 March - | | | | | | | | | |
| No Sod | 250 | 0 | 0 | 11 | 11 | 23 | 23 | 66 | 66 |
| Buffalo | 250 | 2 | 3 | 8 | 7 | 4 | 11 | 86 | 90 |
| Buffalo/Clover | 250 | 5 | 5 | 4 | 3 | 2 | 1 | 89 | 91 |
| Buffalo/Orchard | 250 | 4 | 4 | 4 | 4 | 2 | 6 | 90 | 86 |
| 1994 April - Oct | | | | | | | | | |
| No Sod | 200 | 0 | 0 | 17 | 15 | 22 | 31 | 61 | 54 |
| Buffalo | 200 | 6 | 4 | 14 | 15 | 19 | 27 | 60 | 54 |
| Buffalo/Clover | 200 | 9 | 4 | 9 | 8 | 14 | 32 | 65 | 55 |
| Buffalo/Mulch | 200 | 7 | 3 | 7 | 8 | 15 | 22 | 72 | 67 |

*

For significance of these numbers, refer to earlier tables.

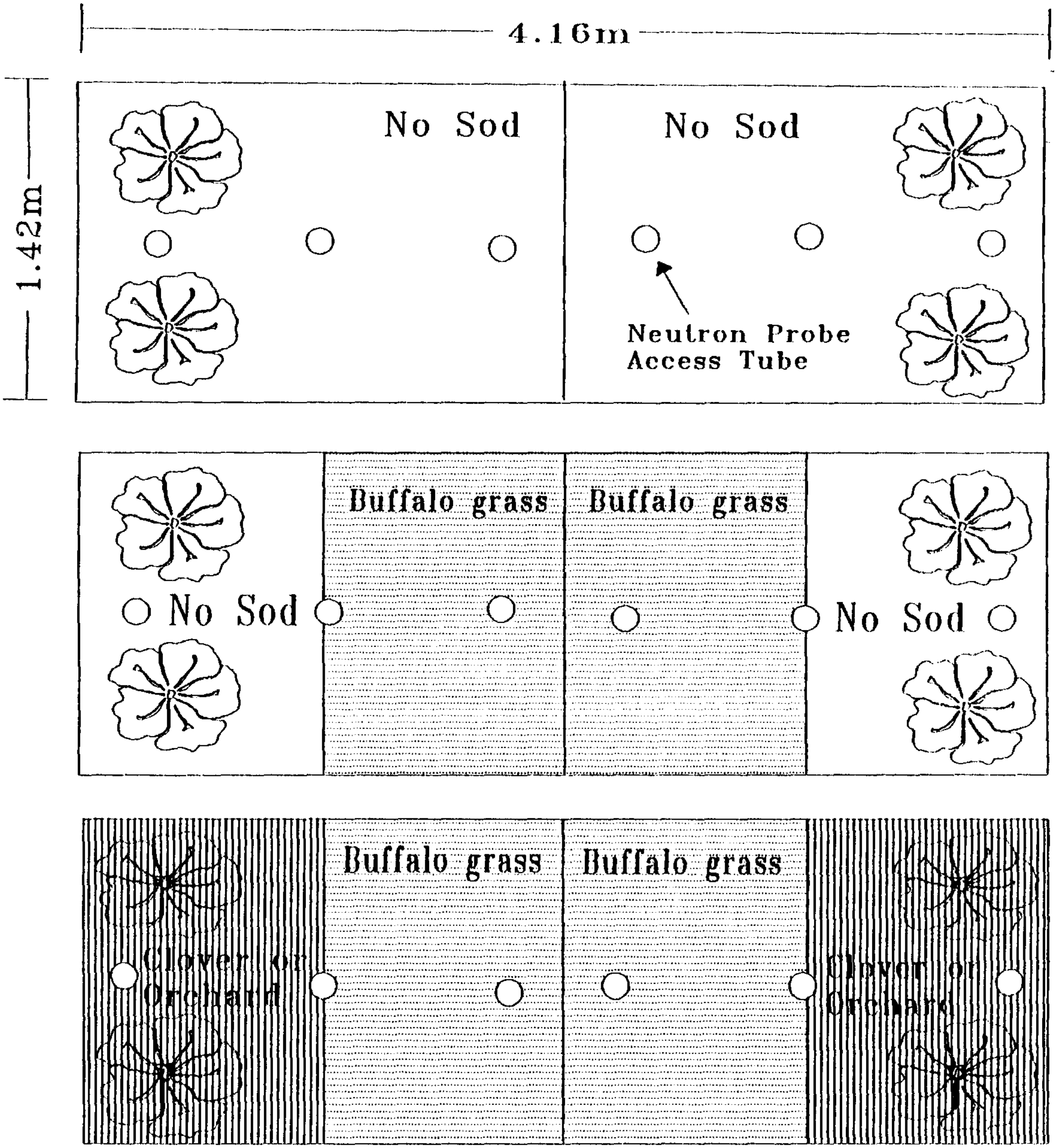


Figure II-1 The aerial view of a section of lysimeter assembly planted to pistachio seedling trees and various sod species.

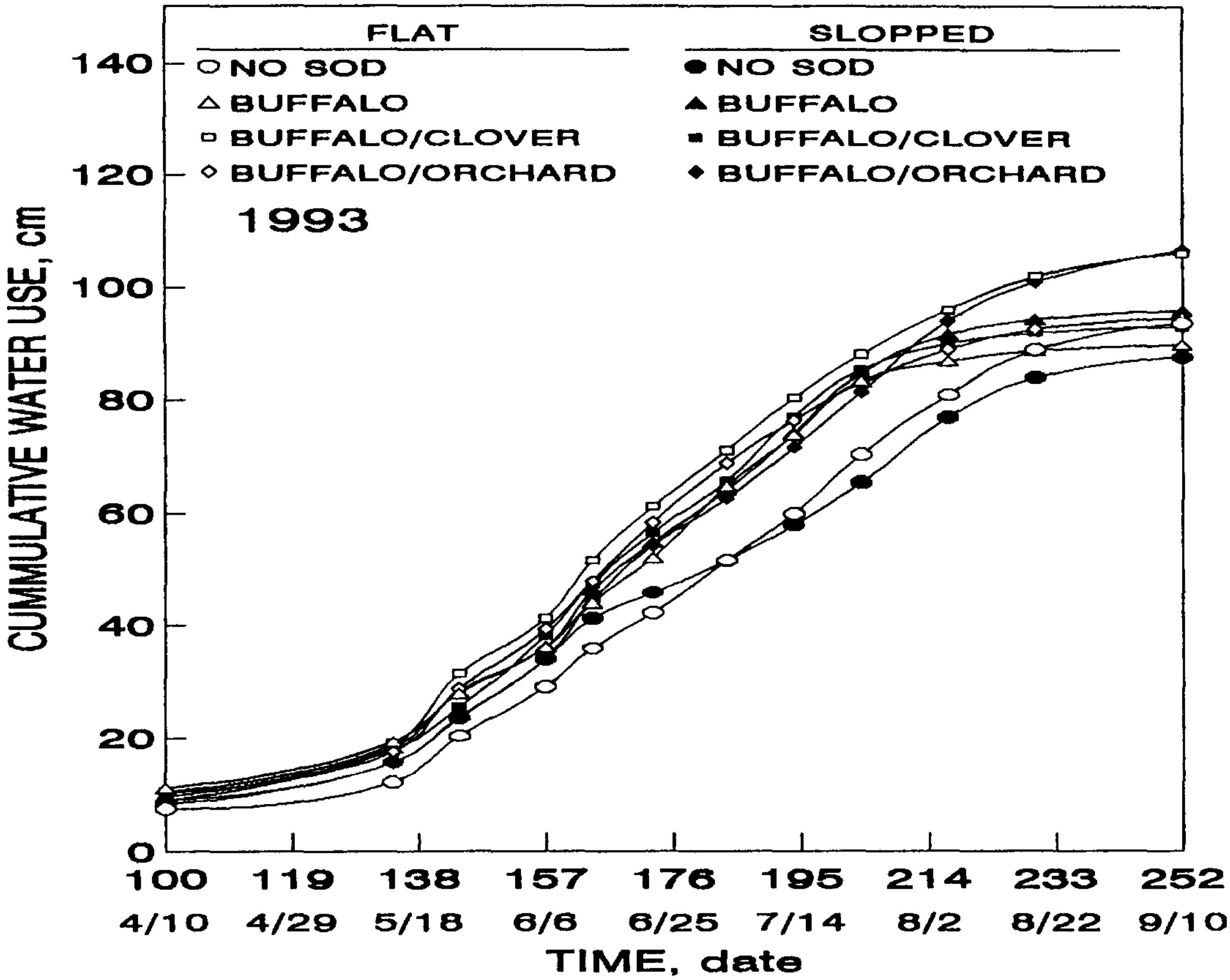


Figure II-2A The seasonal water use of pistachio seedling trees grown under various floor management practices during the 1993 season.

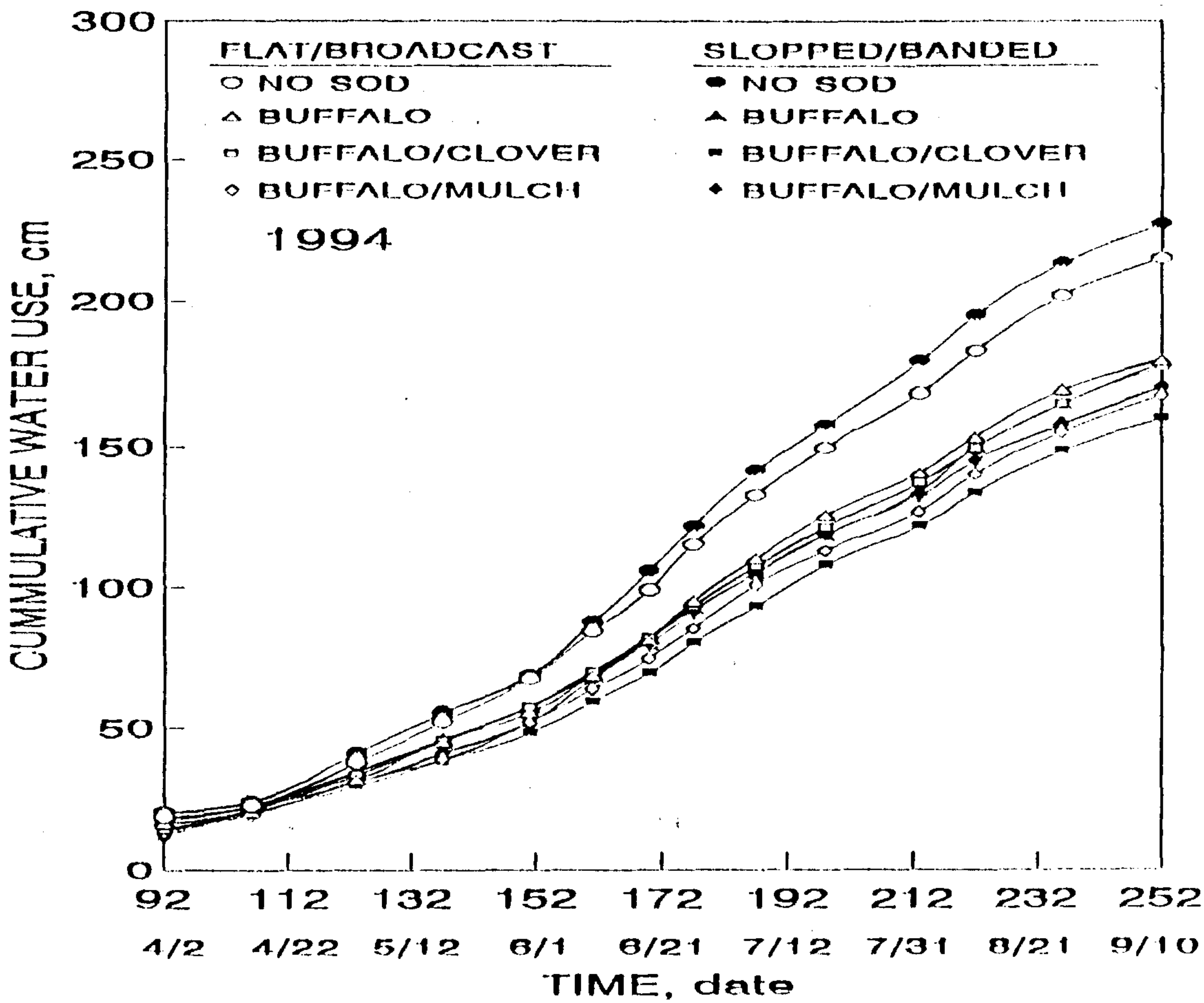


Figure II-2B The seasonal water use of pistachio seedling trees grown under various floor management practices during the 1994 season.

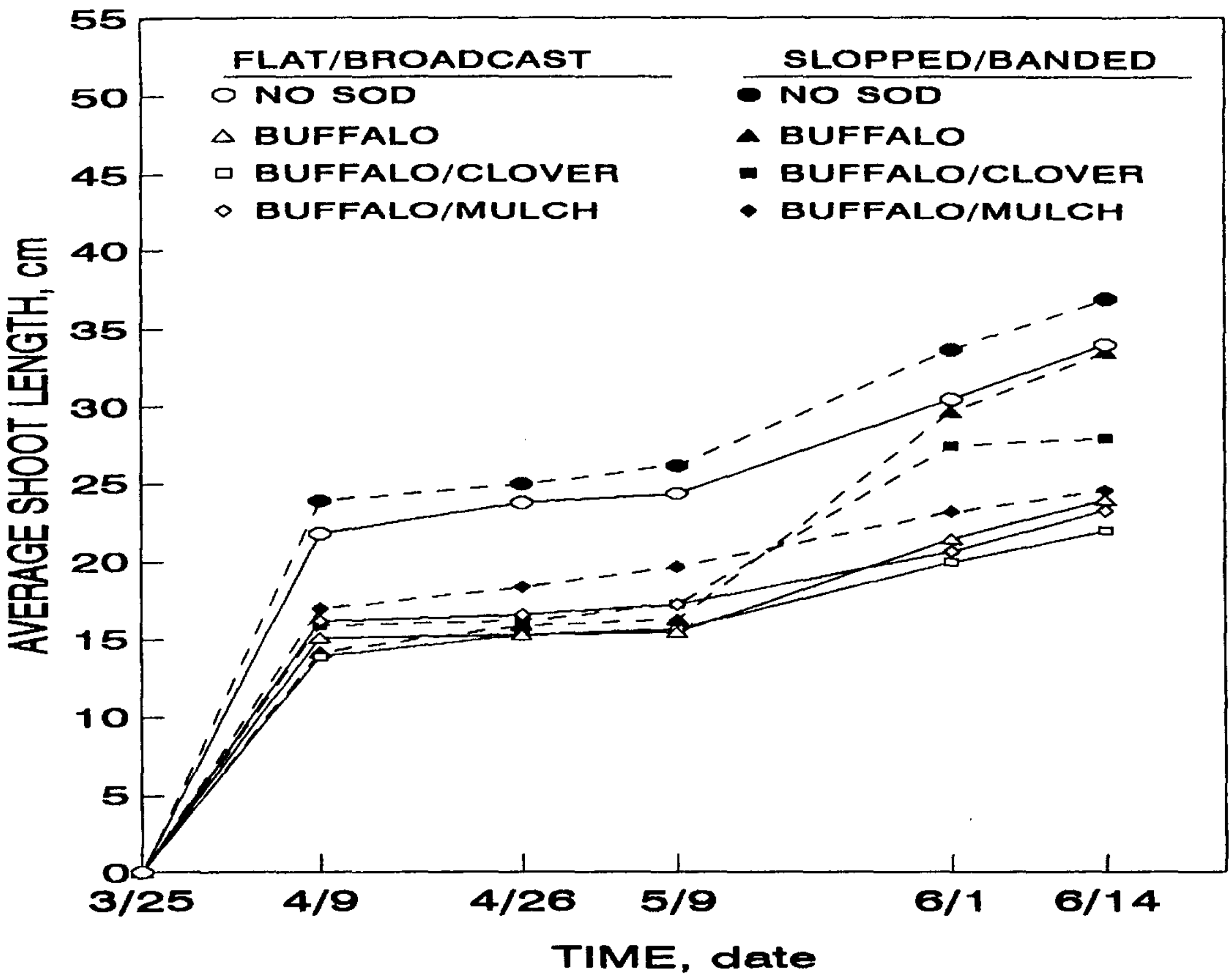


Figure II-3 The shoot growth of pistachio seedling trees grown under floor management practices: measured during the 1994 season.

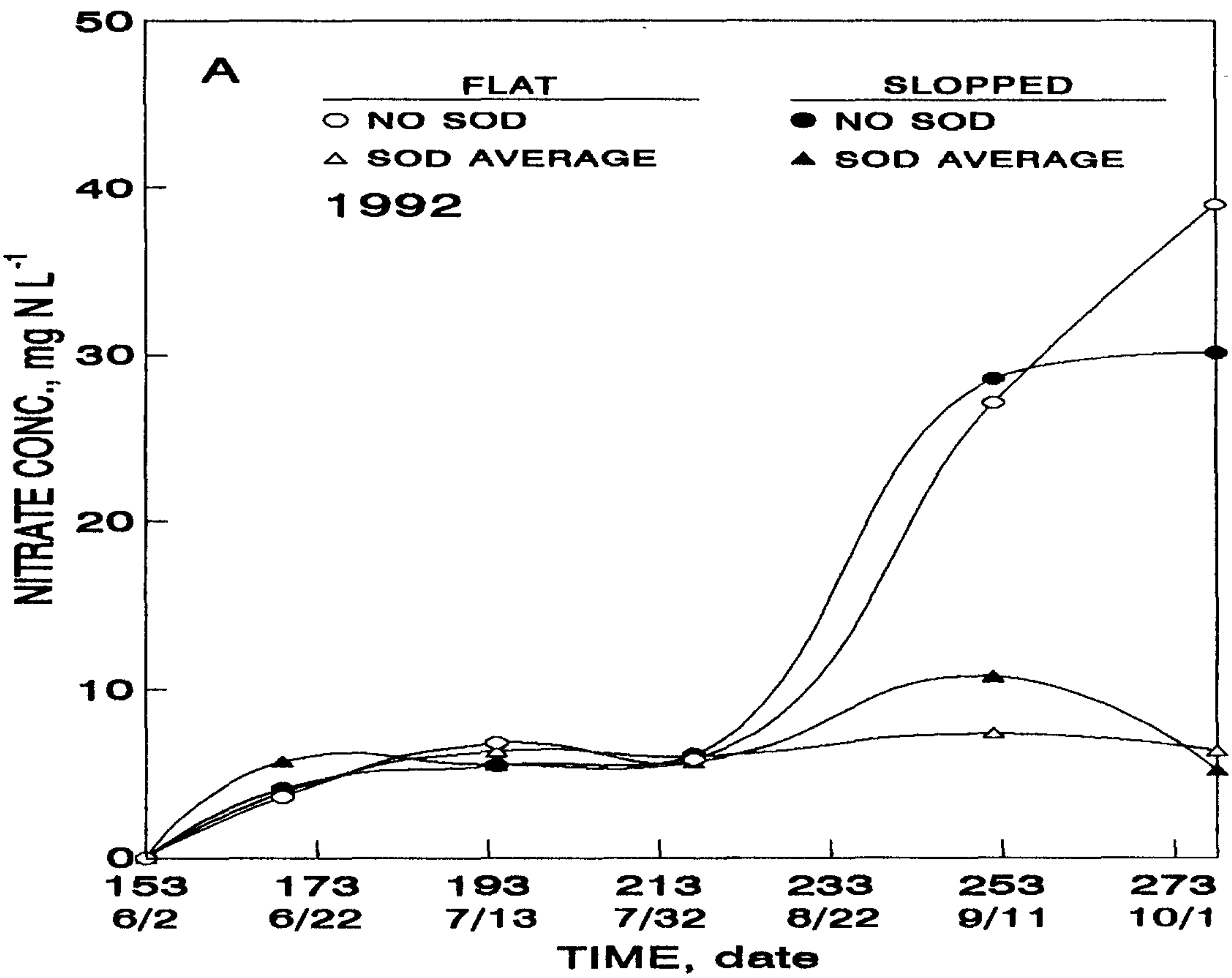


Figure II-4A Nitrate concentrations in drainage water under various floor management practices during the 1992 season.

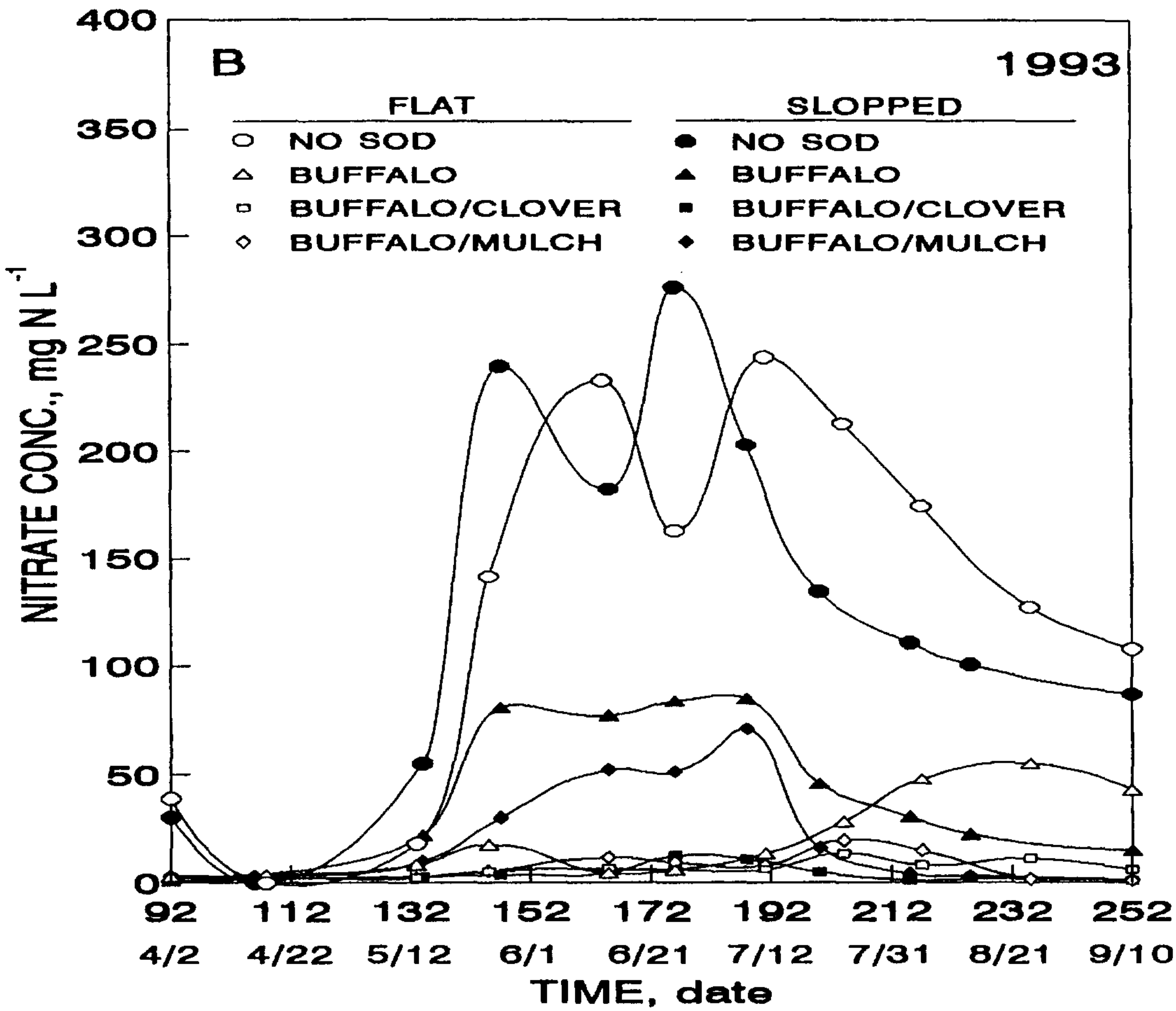


Figure II-4B Nitrate concentrations in drainage water under various floor management practices during the 1993 season.

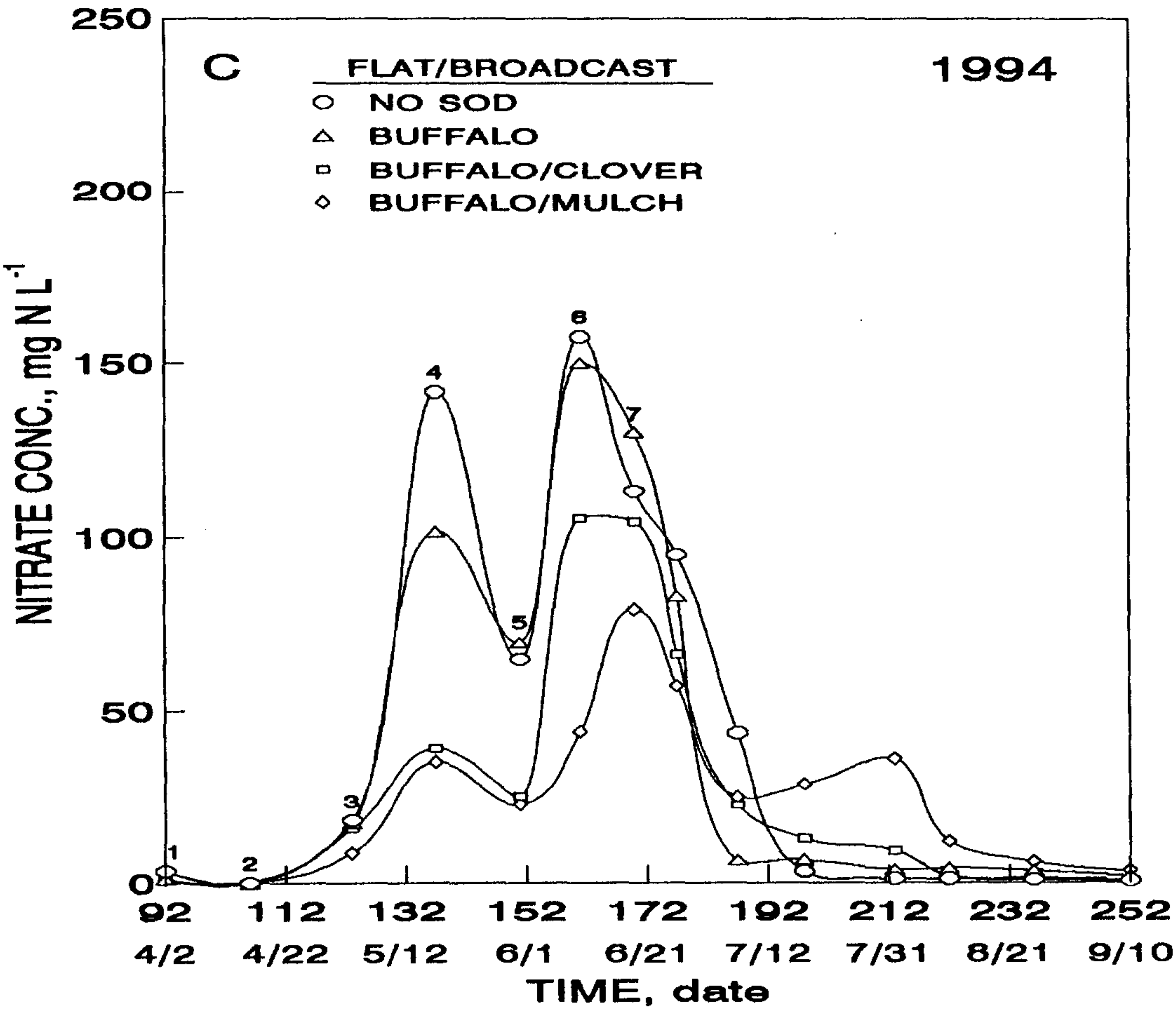


Figure II-4C Nitrate concentrations in drainage water when ammonium sulfate was broadcast on the flat ground surfaces, during the 1994 season.

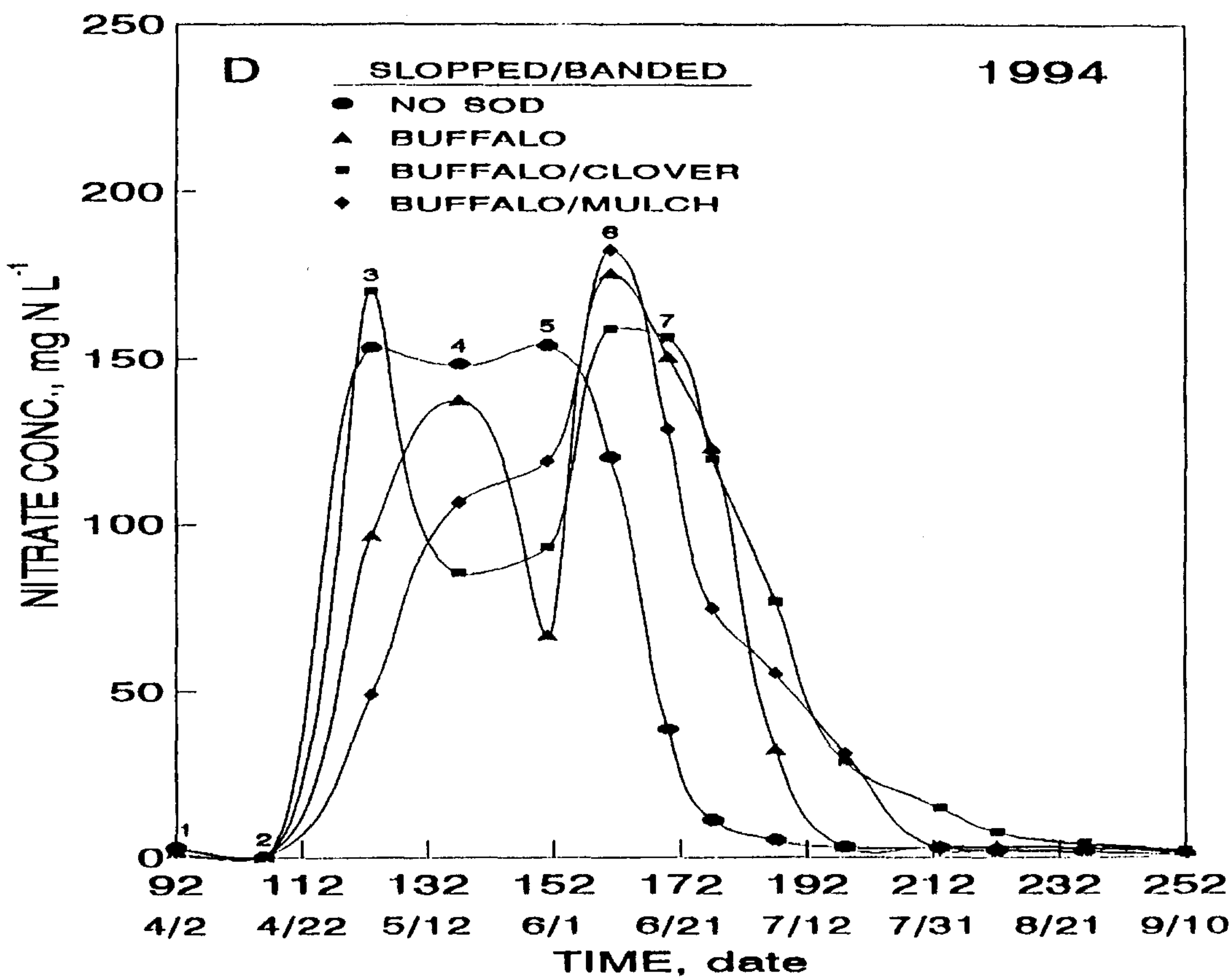


Figure II-4D Nitrate concentrations in drainage water when ammonium sulfate was banded on the slopped ground surfaces, during the 1994 season.

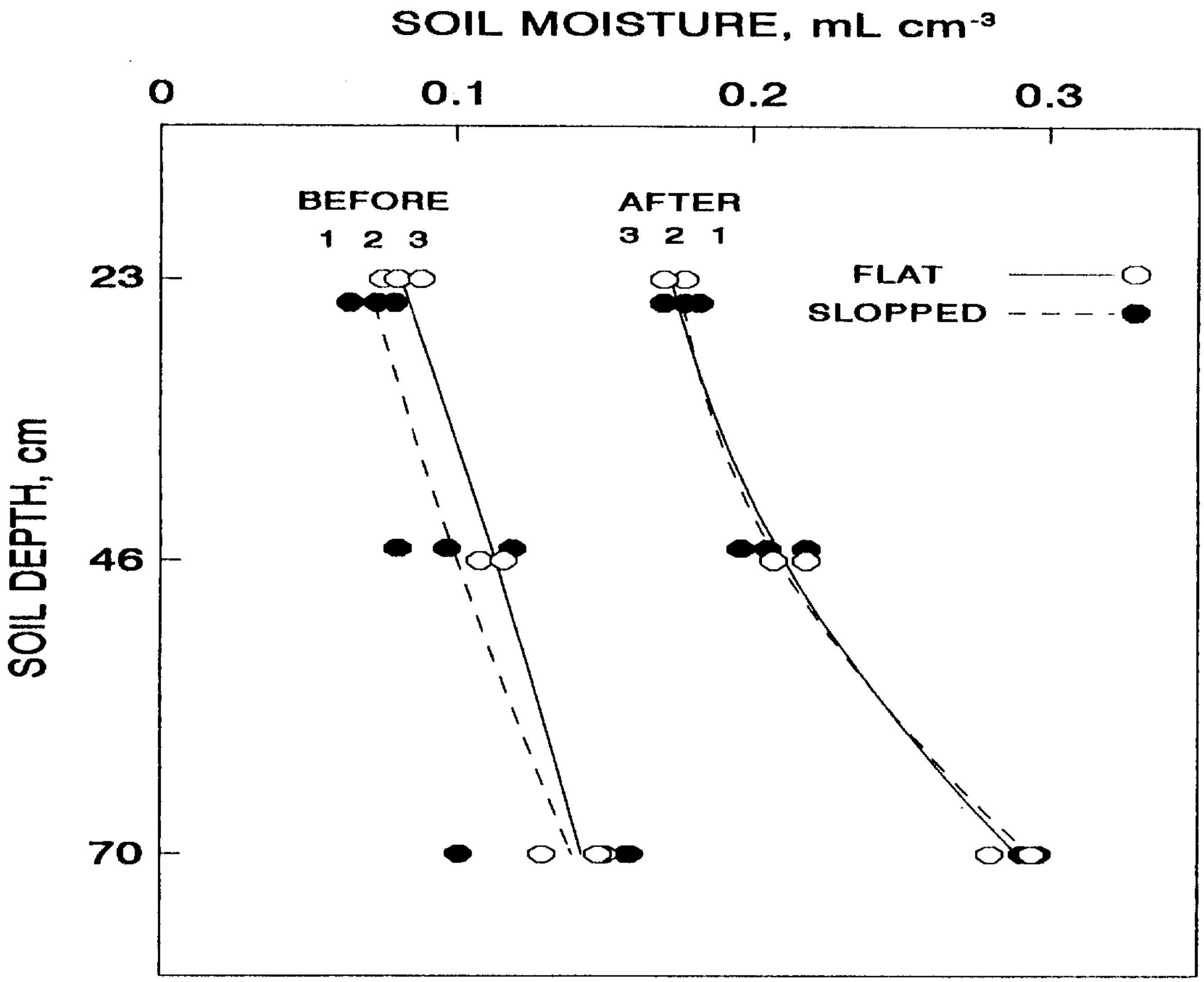


Figure II-5 Soil water contents at three depths before and after irrigation under the flat and slopped ground. The numerals adjacent to the lines indicate the horizontal position from the tree rows; 1: closest to the trees, 2: the middle, and 3: furthest from the trees.

# III. FIELD EVALUATION USING MICROSPRINKLER IRRIGATION IN SODDED AND NONSODDED CITRUS ORCHARD.

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## 1. Introduction

The prevailing citrus orchard management system used in Texas consists of surface flooding over the herbicide-treated ground. Water use efficiency under this system is very low (Swietlik, 1992) because of high percolation losses in areas of low root densities. These losses may also accentuate leaching of nitrogen fertilizers and pesticides.

Trickle irrigation in citrus orchards substantially improved water use efficiency without negatively affecting tree growth, yield, and fruit quality (Swietlik, 1992; Leyden, 1975a, 1975b). Trickle irrigation also reduced nitrate leaching compared to flood irrigation (Swietlik, 1995). There are, however, no local data on water requirements and $NO_3$ leaching potential in orchards irrigated with microsprinklers which are gaining popularity because of their freeze protection capability. This feature is highly important as two tree-killing freezes occurred in the Lower Rio Grande Valley in the 80s.

The presence of vegetative ground cover, commonly referred to as sod, provides the benefit of reduced use of herbicides which are becoming very expensive and also are a potential source of environmental pollution. The presence of sod in an orchard, however, could increase the trees' irrigation water and fertilizer requirements. To minimize the sod's competition, ground covers could be established only in the row middles, leaving weed free herbicide strips within the rows. Coupled with microsprinkler irrigation which applies water and fertilizers only to the soil near the plant, this system should greatly diminish the problem of increased water and fertilizer requirements under an overall sod system.

It is also hypothesized that due to a greater proliferation of tree roots under the weed-free strips, the interception and recovery of fertilizer nitrogen will be improved thus resulting in less nitrate leaching.

The purpose of this field study was to elucidate the effect of sod on nitrate leaching, water use, vegetative growth, and fruiting of a young grapefruit orchard. Also, it provided an opportunity to estimate the potential water savings under microsprinkler vs. flood irrigation in the orchard's early years.

## 2. Materials and Methods

Balled-and-burlaped trees of 'Rio Red' grapefruit on sour orange rootstock were planted in March 1991 in Weslaco, Texas on land with Cameron silty clay soil (mixed, hyperthermic Vertic Haplustolls). The orchard floor was covered with a dense stand of King Ranch bluestem [Bothriochloa ischaemum (L) Keng. var. songarica (Rupr.) Celarier and Harlan] grass. The trees were flood-irrigated until 1992 at which time a microsprinkler irrigation system was installed using one 20 gal/hr Maxijet microsprinkler per tree. Irrigations were initiated at 20 cb soil suction as measured with tensiometers at 30 and 60cm depths.

With each irrigation applied from January to July or August, a liquid nitrogen fertilizer $NO_3$: $NH_4$=1:1 was injected into the irrigation lines to give 200 mg $l^{-1}$ N concentration. The total N supplied per tree per year was 100 g in 1992, and 300 g in 1993 and 1994 (10 and 30 kg N/ha of orchard respectively or 142 and 426 kg N/ha of area treated, respectively).

Three different soil management systems were established in June 1992: 1) G= King Ranch bluestem sod with 1.2 m-wide herbicide strips within tree rows ; 2) HS=King Ranch bluestem sod with 2.4m-wide herbicide strips within tree rows; and 3) OH= an overall herbicide system with herbicides applied to the entire orchard floor. Each treatment was replicated 4 times with 4 trees per replication arranged in completely randomized blocks.

The measurements included: tensiometer readings, soil moisture readings with a neutron probe down to 2.4 m depth in the row middles (not fertilized, and not irrigated), tree height, canopy diameter, trunk cross sectional area (TCSA), leaf N concentration, total fruit yield, and yield by various commercial fruit size categories. Tree canopy volume was calculated using the following formula: Volume=$0.524ad^2$, where a= tree height, and b= canopy diameter.

In 1993, three PVC wells per treatment were installed in the soil to a depth of 4 m, one in each of the first three replicated blocks. In addition, three control wells were placed in the area between the tree rows where no irrigation water and no N have been applied. Water samples were taken from the water table and analyzed for $NO_3$ and $NH_4$. Since only traces of $NH_4$ were occasionally found in the samples, the ammonium data have been omitted in this report. All the data were analyzed statistically using Analysis of Variance. Means were separated with Duncan's Multiple Range Test at $P < 0.05$.

## 3. Results

### a. Shallow Ground Water $NO_3$-N Level.

In 1993, only a trace of nitrates was found in the control wells and those installed in the G treatment (Table III-1). The same was true for all the treatments at the December 1 sampling. Until November 10, however, elevated concentrations of nitrates were present in the samples obtained from the wide strip and especially the overall herbicide treatment. These concentrations, however, did not exceed the primary drinking water standard of 10 mg $l^{-1}$ $NO_3$-N

On January 26, 1994 the $NO_3$-N concentration was highest in the OH treatment, intermediate in the HS treatment, and lowest in the control and G treatments (Table III-2). On the remaining dates in 1994, $NO_3$-N concentrations tended to be higher in the OH, HS, and G treatments compared to the control. However, due to high data variability these differences were seldom statistically significant. For example, nitrate concentration was higher in the HS treatment than in the control on May 10 and it was higher in the G treatment than in the control on June 23 and September 15. On no date were the differences between the three soil management systems statistically significant except on May 10 and June 6 when the concentration of $NO_3$-N was lower in the G treatment than in the HS and OH treatment, respectively. As in 1993, the concentrations of $NO_3$-N were well below the primary drinking water standard in all treatments.

### b. Water Use and Soil Water Content.

At the experiment's onset in 1992 no differences were noted in the amount of irrigation water used under the three soil management systems (Fig. III-1, Table III-3). A few weeks after treatment, however, the G treatment resulted in increased irrigation amounts compared to HS and OH treatments. Not until the middle of 1993 did differences appear between the OH and HS treatments. The HS treatment resulted in higher irrigation amounts compared to the OH and G treatments. In 1994, however, the amount of irrigation water used was similar between all treatments. Over the three years of experiment, trees in the G treatment used the largest amount of irrigation water followed by trees in the HS and OH treatments (Table III-3).

Outside the irrigated zones, soil water content at 30 cm depth was reduced under the G and HS treatments compared to the OH treatment on most of the dates of soil moisture measurements (Figure III-2). The differences were smaller or even nonexistent during autumn, winter, or spring months. The differences between OH vs. G and HS were progressively smaller with each successive year of the study. A similar pattern of differences in water content were found at 60, 90, and 120 cm depths although the differences were rather small at 120 cm depth (Figures III-3, III-4, and III-5). At depths extending from 150 to 240 cm, no differences were found between the treatments (Figures III-6, III-7, III-8, and III-9).

### c. Leaf N Concentration, Tree Growth, Yield, and Yield Efficiency.

Leaf N concentrations were within the optimal range for all treatments as measured in September of 1993 and 1994, i.e., at the year's most optimal time for assessing the tree nutritional status (Table III-4). Leaf N concentrations were higher in the OH and HS than G treatment in 1993, but the difference was negligible from a practical standpoint.

Canopy width, tree height, canopy volume, and trunk cross sectional area (TCSA) were significantly lower in the G than OH treatment at the end of the study (Table III-5). Also, canopy width and volume were significantly smaller in the HS than OH treatment but they were significantly larger compared to trees in the G treatment.

Trees produced their first crop in 1994. Total yield was higher in the HS than G treatment (Table III-6). In the OH treatment, it was intermediate and did not statistically differ from the HS and G treatments. No differences were found between the treatments in terms of the yield of fruit # 48 and larger. Fruit this large usually are marketed fresh to secure higher returns than those realizable from sales of smaller fruit destined for processing.

Yield efficiency, expressed as the yield per unit of canopy volume, was highest in the HS and lowest in the OH treatment (Table III-6). Yield efficiency in the G treatment was intermediate and did not differ from the HS and OH treatments.

## 4. Discussion

### a. Implications for $NO_3$ Leaching.

The hypothesis that the presence of sod would reduce concentration of nitrates in the ground water was supported by the data collected till January 1994 when only traces of $NO_3$-N were found in the G treatment (Tables III-1 and III-2). Moreover, during 1993, the level of $NO_3$ in the HS treatment tended to be lower than that in the OH treatment (Table III-1). The 1994 data, however, proved that the sod merely delayed the appearance of $NO_3$ in the ground water (Table III-2) as no distinct differences existed between the management systems with and without the grass cover by the end of the study.

The mechanism of the sod's initial beneficial effect is not clear. The possibility of increased recovery of nitrogen fertilizer by the trees must be discounted as not supported by the leaf N data which showed no differences between various soil management systems. More likely, biological fixation by soil microorganisms and/or the sod itself were involved, particularly where the sod was in close proximity to the trunks as in the G treatment.

Although $NO_3$-N was present in the ground water under all management systems, its level was well below the primary drinking water standard of 10 $mg \bullet l^{-1}$ $NO_3$-N. Thus, microsprinkler irrigations scheduled based on tensiometers were quite effective in preventing excessive nitrate leaching, regardless of the soil management system used. This finding concurs with an other local study in which a comparison was made between traditional flood and trickle irrigations scheduled on tensiometer readings (Swietlik, 1995).

A further reduction of nitrate leaching would be possible if additional improvements in irrigation efficiency and fertilizer N recovery were realized. This could possibly be achieved by mulching the herbicide strips with a variety of waste materials, e.g., wood chips available from a number of local municipalities. Not only would that counteract a downward movement of water and nitrates but also, through improving soil physical conditions, could potentially improve the recovery of fertilizer N by trees. This possibility will be elucidated in the second phase of this study.

**b. Implications for Herbicide Use.**

The use of herbicide strips vs. the overall herbicide system reduced the use of herbicides by 66% and 84% in the HS and G treatments, respectively. Respective costs of weed control were lowered by 42% and 52% (Table III-7). One must realize, however, that the reduced herbicide costs in the HS and G treatments were partially offset by the additional cost of mowing the middles, a practice not required under the OH system. Nevertheless, the reduced costs of weed control were significant and, importantly, achievable without sacrificing yield (Table III-6).

**c. Implications for Tree Growth and Yield.**

As the HS and G treatments reduced canopy width by 10% and 20%, respectively, the trees under these two systems could be planted more closely compared to the OH system. Assuming a standard spacing of 7.3 x 3.7 m (370 trees/ha) under the OH system, trees in the HS and G treatments could be set at 6.6 x 3.3 m (459 trees/ha) and 5.8 x 3.0 m (575 trees/ha) spacings, respectively. A simple calculation implies that with these adjusted spacings, trees in the HS and G treatments had the potential to produce 19.6 and 14.9 tons of fruit per ha, respectively, compared to 11.6 tons/ha in the OH treatment. As this study was short term, however, the data collected over a longer period are needed to verify these preliminary estimates.

**d. Implications for Water Use.**

The sod's competition for water was clearly evident in the G and HS treatments as illustrated by the respective 20% and 14% increases in the water use per tree compared to the OH treatment. In the G treatment, some of the irrigation water was absorbed directly by the sod as the wetted zones extended beyond the narrow herbicide strips. This was not so in the HS treatment where the wetted zones were contained within the wide herbicide strips. Due to the presence of sod, however, the soil in the row middles was drier in the G and HS than OH treatment. Consequently, in the sodded treatments the roots outside the irrigated zones had to compete with the sod for the rain water stored in the middles. This competition manifested itself by higher irrigation needs in the G and HS treatments although they were mitigated by smaller tree canopies in these two treatments in the third year of study.

The differences in the water use between treatments would have been even larger if the water use were expressed on a per ha basis and adjustments were made for possible increases in planting densities in the HS and G treatments as discussed above. Assuming tree densities of 370, 459, and 575 per ha in the OH, HS, and G treatments, respectively, the water use per ha would total 2014; 2846; and 3746 kl(kiloliters)/ha over a three year period. This increased water use in the HS and G treatments would amount to an additional water cost of $5.40 and $11.23/ha/year, respectively. These amounts are small compared to the savings on weed control realized under the G and HS treatments.

Although no direct comparisons were made in this study between the water use in microsprinkler- and flood-irrigated orchards, some tentative estimates are possible. Under the climatic conditions of the Lower Rio Grande Valley, typically five flood irrigations are applied per year in orchards kept under an overall herbicide system. Assuming that in a young orchard growers irrigate only strips of soil in tree rows rather than the whole orchard floor, the amount of water used over a three year period would amount to 11,562 kl/ha. This is approximately 3, 4, and 5.7 times as much as the amount utilized under the G, HS, and OH treatments, respectively.

## 5. Conclusions

1. Scheduling microsprinkler irrigations based on tensiometer readings resulted in nitrate concentrations in the ground water well below the primary drinking water standard of 10 $mg \bullet l^{-1}$ $NO_3$-N, three years after treatment initiation.

2. The presence of sod in the orchard reduced the level of $NO_3$-N in the ground water two years after treatment initiation but this effect ceased to exist in the third year of the study.

3. The use of microsprinkler irrigation in a young citrus orchard resulted in considerable savings of irrigation water compared to traditional flood irrigation. The savings over a three year period were estimated at 82%, 75%, and 67% in the OH, HS, and G treatments, respectively.

4. The presence of sod in the HS and G treatments resulted in the increased irrigation amounts compared to the OH system. The cost of this additional water, however, was very small compared to savings on herbicide use in sodded vs. unsodded plots.

5. Compared to the OH system, the presence of sod reduced the amount of herbicides used by 84% and 66% in the HS and G treatments, respectively, and resulted in an overall reduction of weed control cost by 42% and 52%.

6. The presence of sod had a dwarfing effect on trees without negatively affecting yield. Consequently, yield efficiency, expressed as the amount of fruit per unit of canopy volume, increased when the sod was present.

7. The preliminary data indicate that the dwarfing effect of sod could possibly aid in managing high density plantings to reap increased orchard production per unit of surface area.

8. Further studies are needed to elucidate the benefits of mulching the herbicide strips to decrease the nitrate leaching and to increase fertilizer N recovery by trees.

Table III-1. The effect of soil management practices in a young grapefruit orchard on $NO_3$-N level in the shallow ground water in 1993 (2nd year).

| Treatment | 9/20/93 | 10/6/93 | 11/3/93 | 11/10/93 | 12/1/93 |
|---|---|---|---|---|---|
| | | | mg $l^{-1}$ | | |
| Control[Z] | 0.06b | 0.03b | 0.60b | 0.53b | 0.33 |
| OH[Y] | 5.47a | 2.50a | 4.60a | 6.10a | 0.97 |
| HS | 4.26a | 2.63a | 3.43ab | 1.27b | 0.50 |
| G | 0.26b | 0.19ab | 0.90b | 0.87b | 0.40 |

[Z] Control wells were placed in the area between the rows where no irrigation water and N have been applied.

[Y] OH = overall herbicide; HS = 2.4 m-wide herbicide strip
G = 1.2 m-wide herbicide strip.

Table III-2. The effect of soil management practices in a young grapefruit orchard on $NO_3$-N level in the shallow ground water in 1994 (3rd year).

| Treatment | 1/26/94 | 4/13/94 | 5/10/94 | 6/6/94 | 6/23/94 | 9/15/94 | 11/28/94 |
|---|---|---|---|---|---|---|---|
| | | | | mg $l^{-1}$ | | | |
| Control[Z] | 0.27c | 0.33 | 0.50b | 1.32ab | 0.12b | 0.44b | 0.12 |
| OH[Y] | 1.59a | 0.87 | 1.72ab | 3.06a | 1.37ab | 2.39ab | 2.10 |
| HS | 0.85b | 2.50 | 2.63a | 2.25ab | 1.11ab | 3.03ab | 1.72 |
| G | 0.25c | 1.70 | 1.28b | 0.70b | 2.13a | 4.40a | 1.84 |

[Z] Control wells were placed in the area between the rows where no irrigation water and N have been applied.
[Y] OH=overall herbicide; HS=2.4 m-wide herbicide strip;
G=1.2m -wide herbicide strip.

Table III-3. Irrigation water use in a young grapefruit orchard as affected by different soil management practices.

| Treatment | Year | | | | Relative Water Use |
|---|---|---|---|---|---|
| | 1992 | 1993 | 1994 | 1992-94 | |
| | l/tree | | | | % |
| OH[z] | 1037 | 2282 | 2123 | 5443 | 100 |
| HS | 950 | 3126 | 2123 | 6200 | 114 |
| G | 1646 | 2858 | 2010 | 6514 | 120 |

[z]/OH = overall herbicide; HS=2.4m wide herbicide strip; G=1.2m wide herbicide strip.

Table III-4. The effect of soil management on grapefruit leaf N concentration.

| Treatment | Leaf N (g $kg^{-1}$ dry wt.) | |
|---|---|---|
| | Sept. 1993 | Sept. 1994 |
| OH[Y] | 24.6a[Z] | 24.3 |
| HS | 24.4a | 23.8 |
| G | 23.6b | 23.8 |

[Z] Means in columns separated by Duncan's Multiple Range Test 5% level.

[Y] OH = overall herbicide; HS= 2.4m wide herbicide strip; G=1.2m wide herbicide strip.

Table III-5. The effect of soil management on growth of young grapefruit trees cv. Rio Red, three years after treatment initiation. Measurements were taken in December 1994.

| Treatment | Canopy | | | TCSA |
|---|---|---|---|---|
| | Width | Height | Volume | |
| | (cm) | (cm) | ($m^3$) | ($cm^2$) |
| OH[Y] | 363a | 278a | 19.3a | 95.9a |
| HS | 328b | 272a | 15.4b | 88.5a |
| G | 291c | 250b | 11.2c | 76.9b |

[Z] Means in columns separated by Duncan's Multiple Range Test, 5% level.

[Y] OH = overall herbicide; HS= 2.4m-wide herbicide strip; G=1.2m-wide herbicide strip.

Table III-6. The effect of soil management on yield and yield efficiency of young grapefruit trees cv. Rio Red. 1994 Season.

| Treatment | Total Yield | Yield Fruit #48 and larger | Yield Efficiency (Yield/Canopy Volume) |
|---|---|---|---|
| | kg/tree | kg/tree | $kg/m^3$ |
| OH[Y] | 31.4 ab [Z] | 23.6 | 1.64 b |
| HS | 42.7 a | 23.6 | 2.86 a |
| G | 25.9 b | 18.6 | 2.55 ab |

[Z] Means in columns separated by Duncan's Multiple Range Test, 5% level.

[Y] OH=overall herbicide; HS=2.4m-wide herbicide strip; G=1.2m-wide herbicide strip.

Table III-7. The annual cost of weed control in a young grapefruit orchard under three different soil management systems.

| Treatment | Preemergence control | | Postemergence control | | Mowing[V] | Total |
|---|---|---|---|---|---|---|
| | Herbicides[Z] | Application[Y] | Herbicides[X] | Application[W] | | |
| | | | U.S. $/ha of orchard | | | |
| OH[T] | 254.55 | 50.00 | 37.23 | 63.75 | 0.00 | 405.53 |
| HS | 84.85 | 16.65 | 12.40 | 21.20 | 100.00 | 235.10 |
| G | 42.45 | 8.35 | 6.23 | 10.60 | 125.00 | 192.63 |

[Z] Two annual applications of Surflan + Simazine at a rate of 2.84 kg a.i./ha each. Prices: 1 kg. a.i. of Surflan = $35.75; Simazine $9.04.

[Y] Cost: $25.00 per ha treated per application.

[X] Four spot treatments with Roundup at 0.75% concentration plus surfactant at 0.25% concentration using 946 l mix per ha treated. It is assumed that only 10% of the area under chemical weed control is spot-treated. Prices: Roundup $12.02/l; Surfactant $3.30/l.

[W] Labor costs: $8.50/hr. It is assumed that only 10% of the area under chemical weed control is spot-treated. The time needed to spot treat 1 ha under chemical weed control = 1.88 hr.

[V] No mowing required under the OH treatment. In the HS and G treatments 4 mowings are needed per year. 1.25 hr is needed to mow 1 ha. 1 hr of tractor work = $30.00.

[T] OH = overall herbicide; HS=2.4m-wide herbicide strip; G= 1.2m-wide herbicide strip.

Fig. III-1. Cumulative water use in a young grapefruit orchard as affected by different soil management systems (1992-1994).

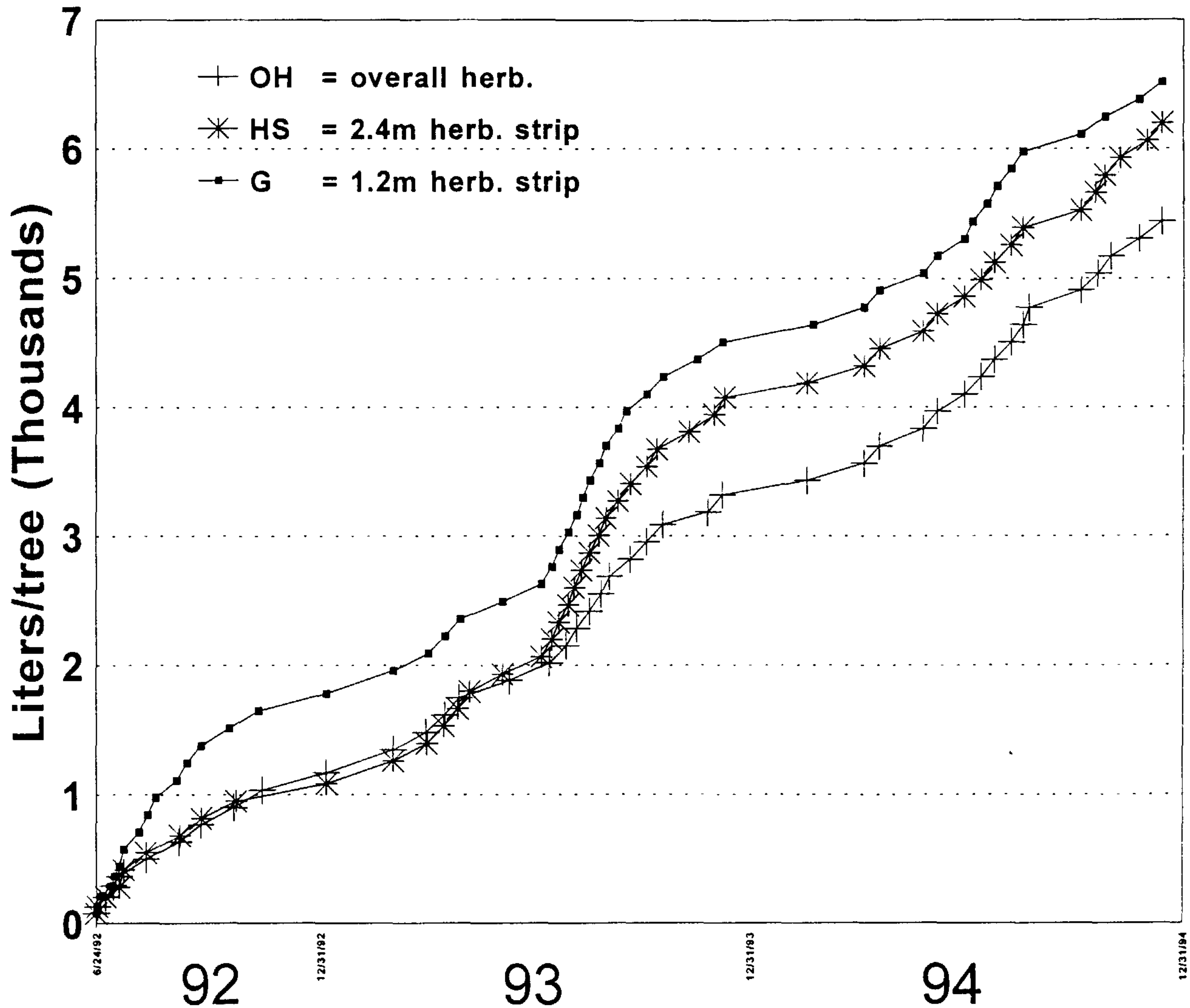


Fig. III-2. Soil water content in the row middles of a microsprinkler-irrigated grapefruit orchard under different soil management systems.

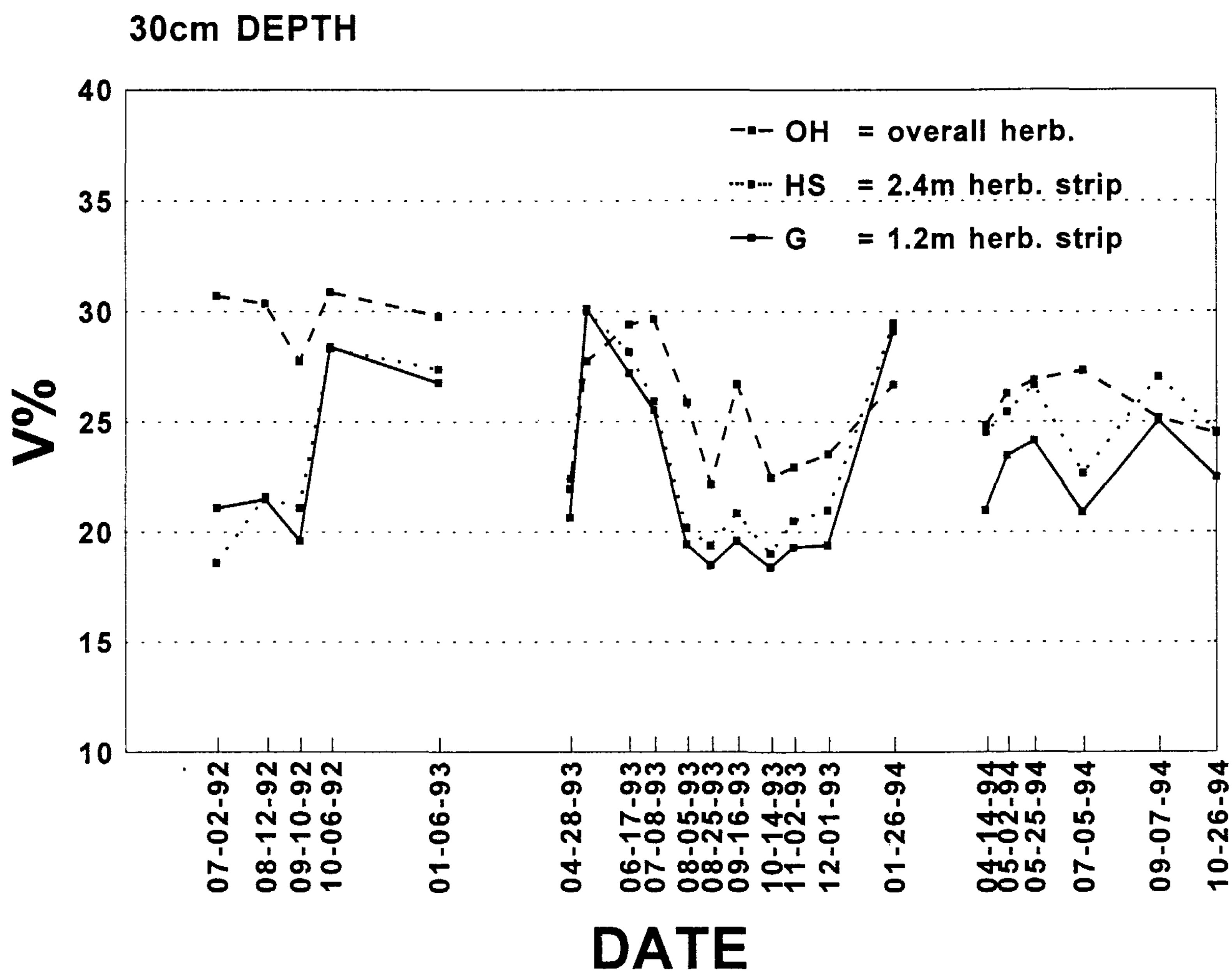


Fig. III-3. Soil water content in the row middles of a microsprinkler-irrigated grapefruit orchard under different soil management systems.

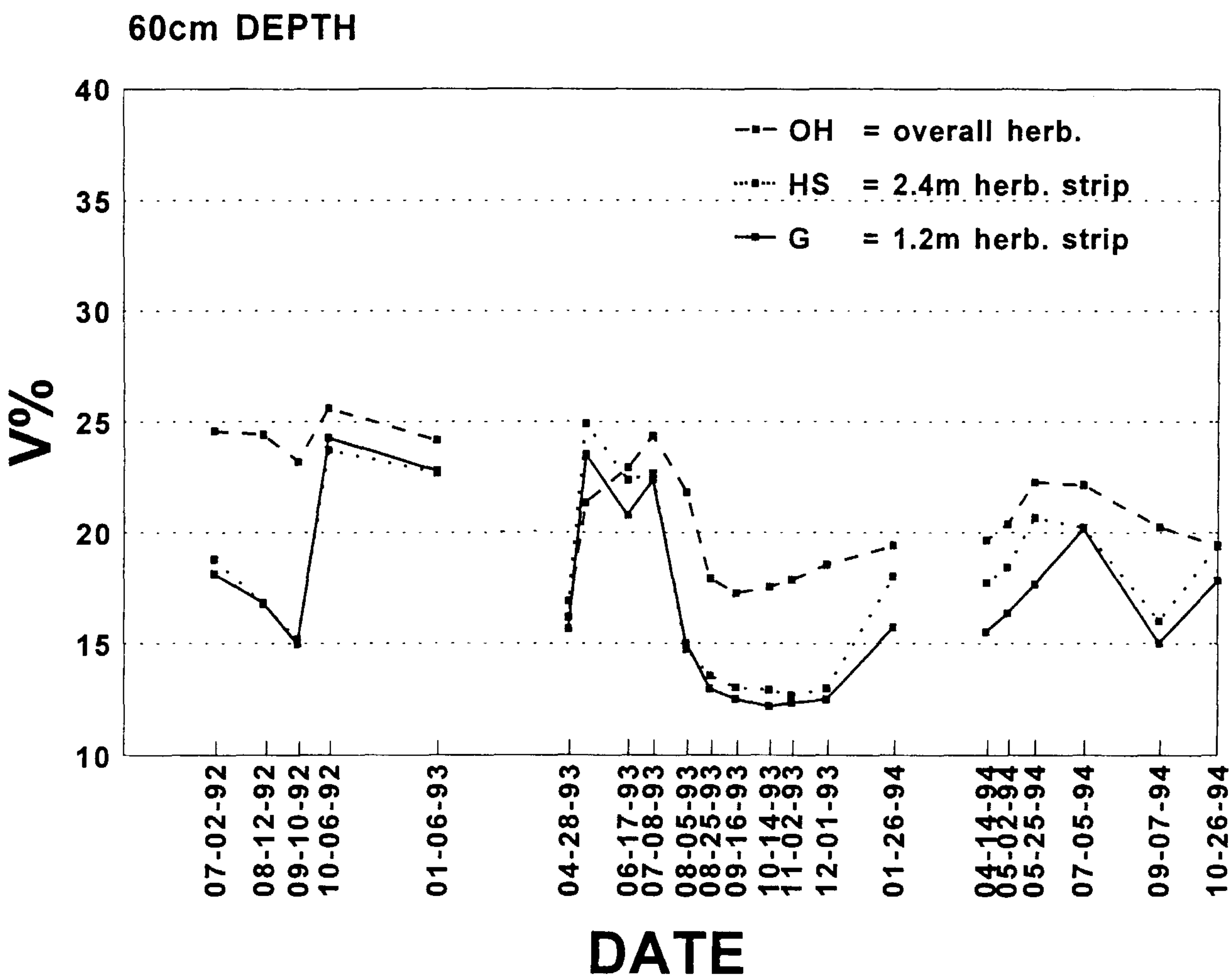


Fig. III-4. Soil water content in the row middles of a microsprinkler-irrigated grapefruit orchard under different soil management systems.

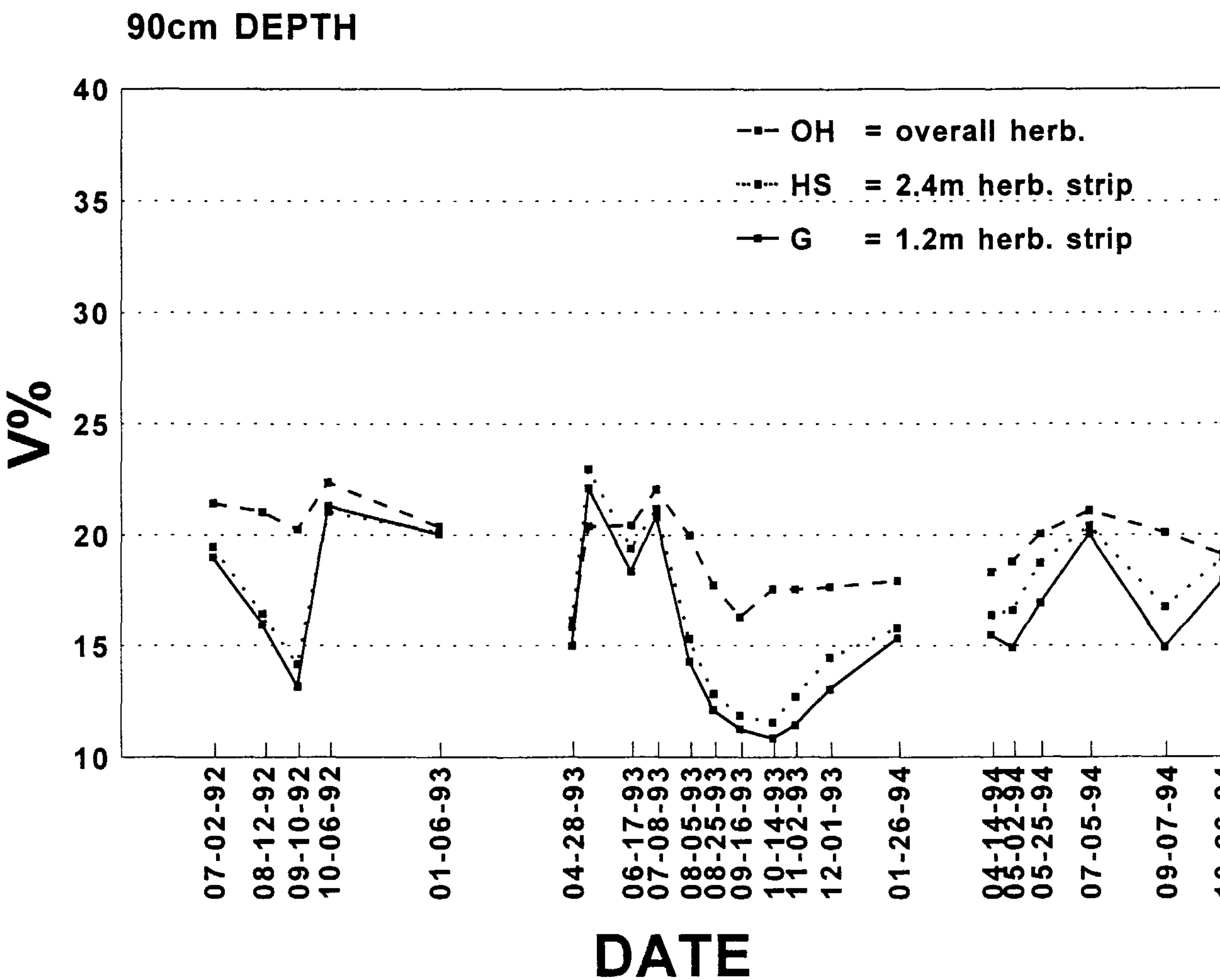


Fig. III-5. Soil water content in the row middles of a microsprinkler-irrigated grapefruit orchard under different soil management systems.

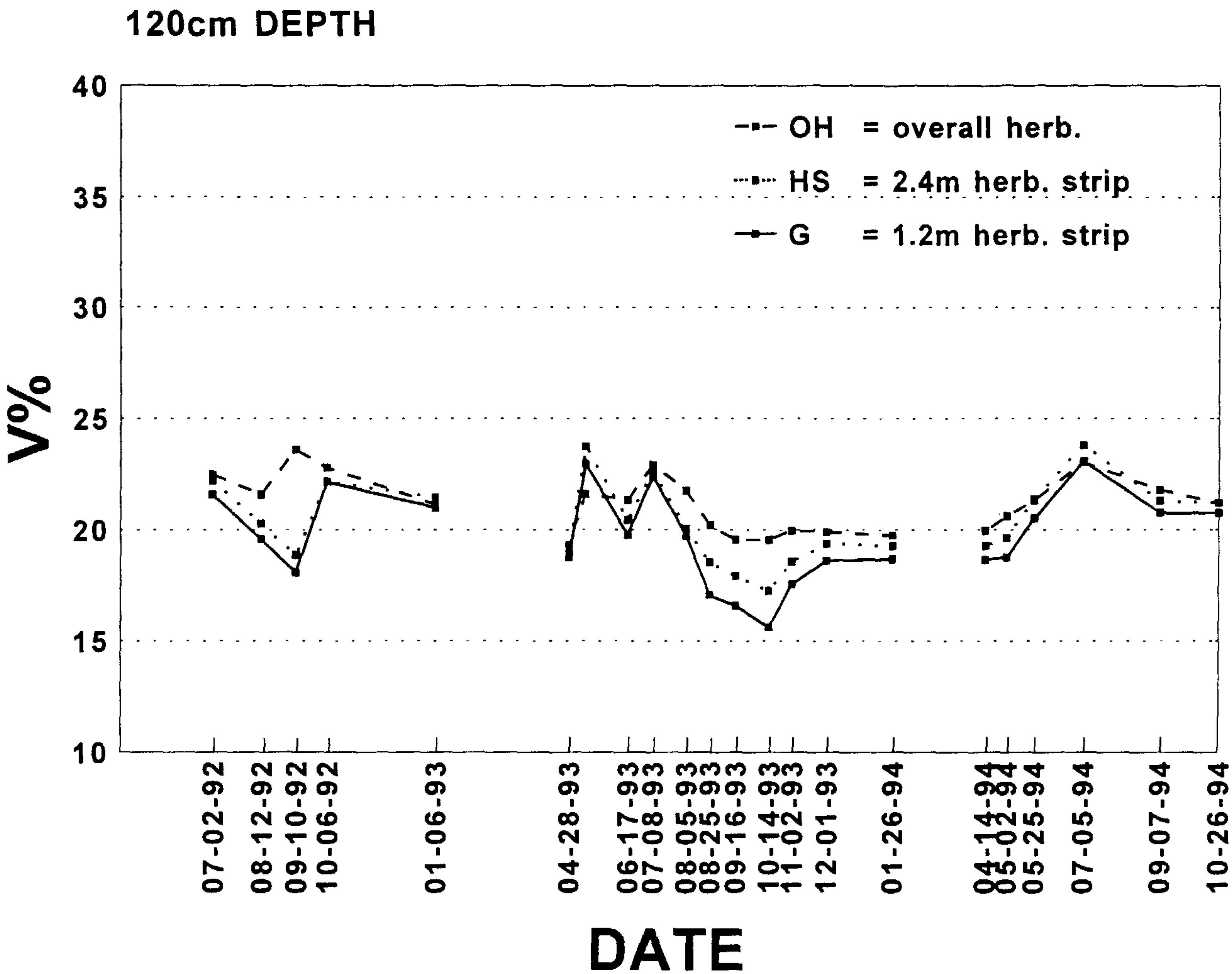


Fig. III-6. Soil water content in the row middles of a microsprinkler-irrigated grapefruit orchard under different soil management systems.

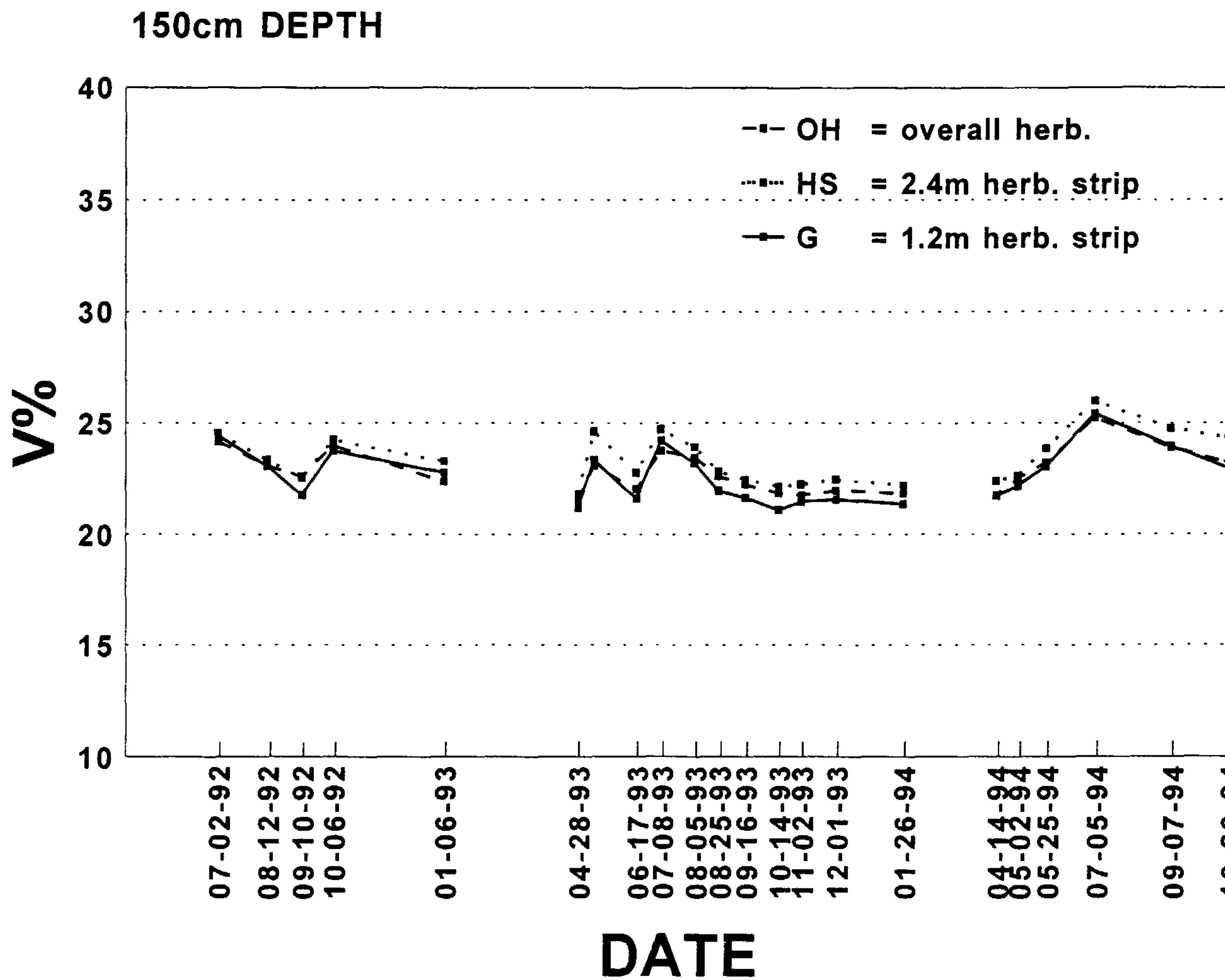


Fig. III-7. Soil water content in the row middles of a microsprinkler-irrigated grapefruit orchard under different soil management systems.

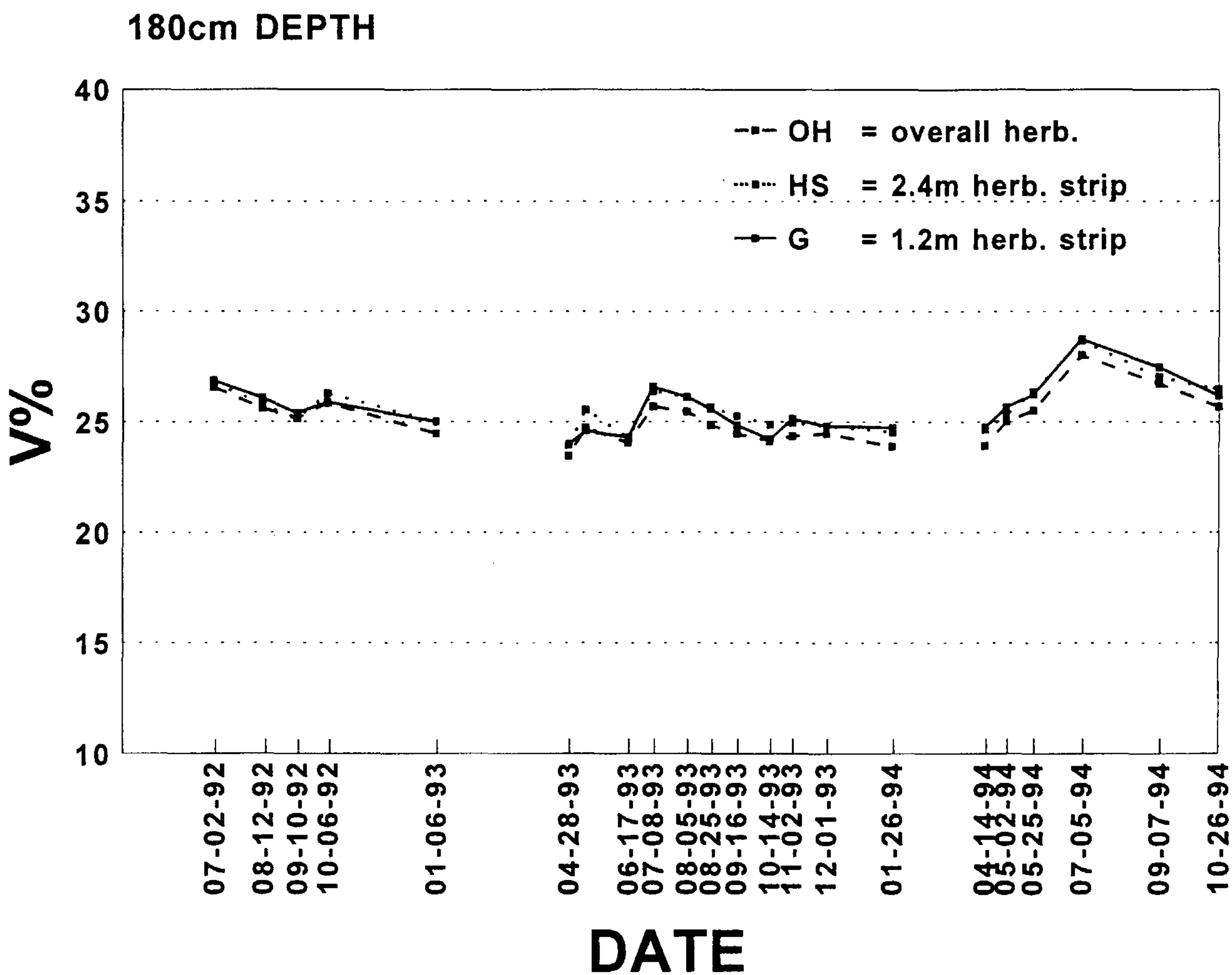


Fig. III-8. Soil water content in the row middles of a microsprinkler-irrigated grapefruit orchard under different soil management systems.

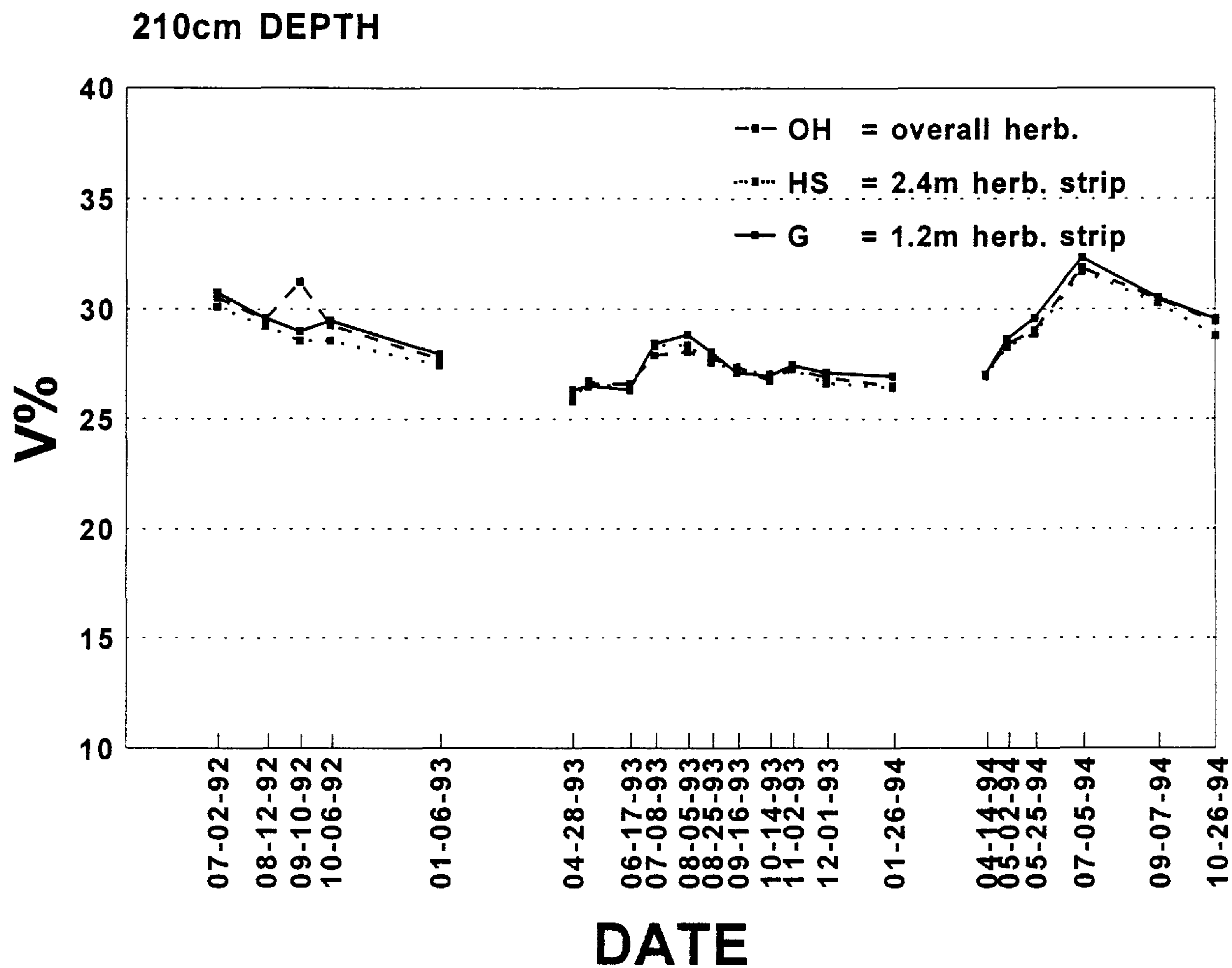
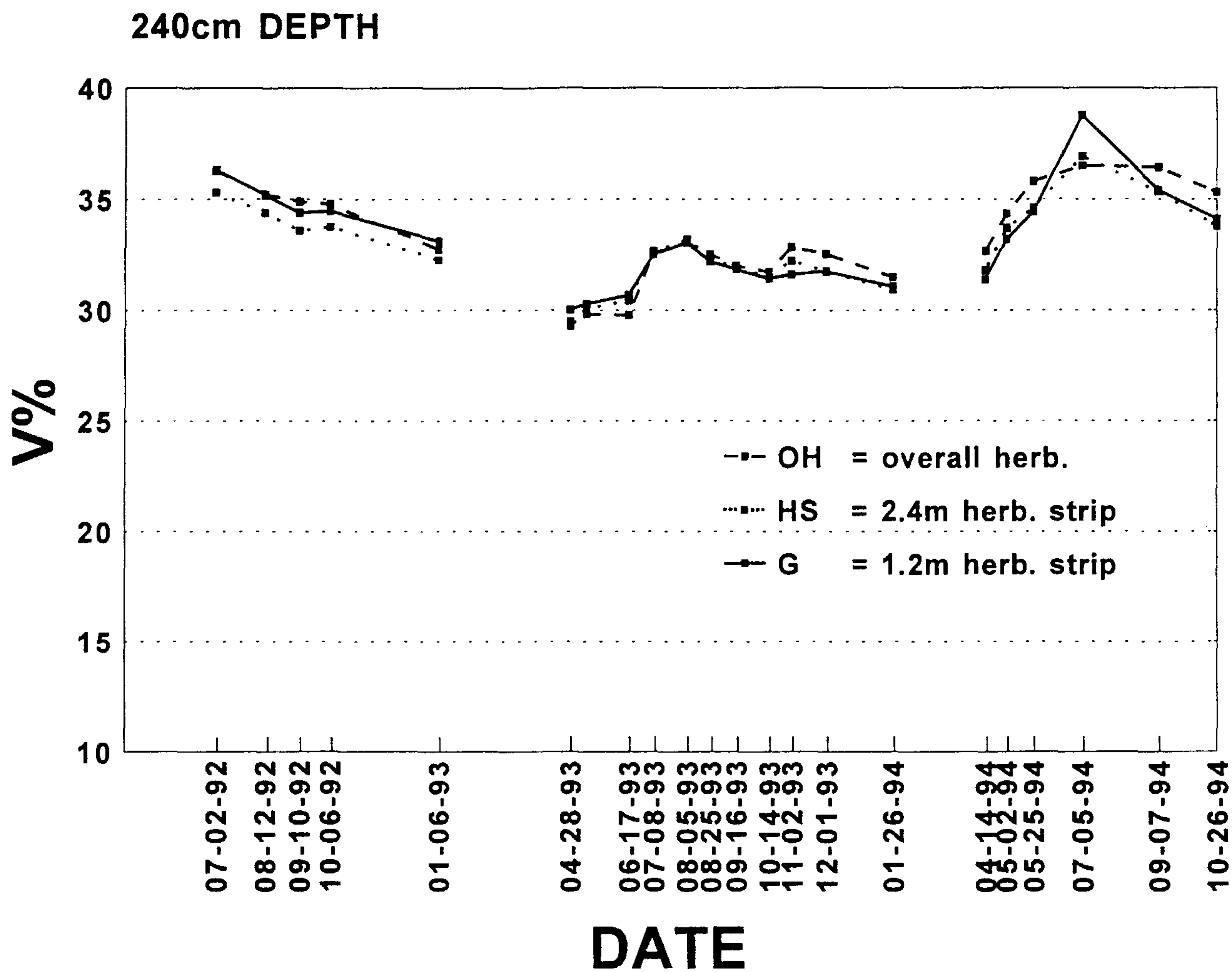


Fig. III-9. Soil water content in the row middles of a microsprinkler-irrigated grapefruit orchard under different soil management systems.



## Literature Cited

Apel, G.W., M.W. Smith, and H.A. Hinrichs. 1979. The effect of ground covers on tree performance and mechanical harvesting. Pecan South. pp 8-11.

Bremner, J.M. 1965. Total N. P1149-1178, In C.A. Black et al. (ed), Agronomy 39, Methods of Soil analysis. Part 2. American Society of Agronomy, Madison, WI.

Busey, P. 1992. Seedling growth, fertilization timing, and establishment of bahiagrass. Crop Sci. 32:1099-1103.

Feldhake, C.M., R. E. Danielson, and J.D. Butler. 1984. Turfgrass evapotranspiration. II: Response to deficit irrigation. 76:85-89.

Florunso, O.A., D.E. Ralston, T. Prichard and D.T. Louie. 1992. Cover crops lower soil surface strength, may improve soil permeability. Calif. Agr. 46:26-27.

Glenn, D.M. and W.V. Welker. 1989. Orchard soil management systems influence rainfall infiltration. J. Amer. Soc. Hort. Sci. 114:10-14.

Glenn, D.M. and W.V. Welker. 1989. Peach root development and tree hydraulic resistance under fescue sod. Hort. Sci. 24:117-119.

Goff, W.D. 1991. Orchard floor management practices influence elemented concentrations in young pecan trees. Hort. Sci. 26:1379-1381.

Jackson, L.E., L.J. Wyland, J.A. Klein, R.F. Smith, and W.E. Chaney. 1993. Winter cover crops can decrease soil nitrate, leaching potential Calif. Agr. 47:12-15.

Leyden, R.F. 1975a. Comparison of three irrigation systems for young citrus trees. J. Rio Grande Valley Hort. Soc. 29:25-30.

Leyden, R.F. 1975b. Drip irrigation on bearing citrus trees. J. Rio Grande Valley Hort. Soc. 29:31-36.

Loyne, R.E.C., and C.S. Tan. 1988. Influence of cultivars, ground covers, and trickle irrigation on early growth, yield, and cold hardiness of peaches on Fox sand. J. Amer. Soc. Hort. Sci. 113:518-525.

Miller, S.S. 1983. Response of young 'Topred Delicious' apple trees to orchard floor management and fertilization. J. Amer. Soc. Hort. Sci. 108:638-642.

Miyamoto, S., L.B. Fenn and D. Swietlik. 1994. Flow, salts, and trace elements in the Rio Grande: A review. Tech Bull (*not yet assigned) TAES, TAMU.

Neilsen, G.H., M. Meheriuk, and E.J. Hogue. 1984. The effect of orchard floor management and nitrogen fertilization on nutrient uptake and fruit quality of 'Golden Delicious' apple trees. Hort. Sci. 19:547-550.

Parker, M.L., J. Hull, and R.L. Perry. 1993. Orchard floor management effects peach rooting. J. Amer. Soc. Hort Sci. 118:714-718.

Schellinger, G.R. and J.C. Clausen. 1992. Vegetative filter treatment of dairy barnyard runoff in cold regions. J. Environ. Qual. 21:40-45.

Steel, R.G.D., and J.H. Torrie. 1960. Principles and Procedures of statistics. McGraw-Hill Book Company, New York.

Swietlik, D. 1995. Minimizing nitrate leaching in citrus orchards with low volume irrigation. Proceedings of the 5th International Microirrigation Congress, April 2-5, 1995, Orlando, Florida. (In Print).

Swietlik, D. 1992. Yield, growth, and mineral nutrition of young 'Ray Ruby' grapefruit trees under trickle or flood irrigation and various nitrogen rates. J. Amer. Soc. Hort. Sci. 117:22-27.

Trudell, M.R., R.W. Gillham, J.A. Cherry. 1986. An in-site study of the occurrence and rate of denitrification in a shallow unconfined sand aquifer. J. Hydol. 83:251-268.

Weier, K.L., and I.C. MacRae. 1993. Net mineralization, net nitrification and potentially available nitrogen in the subsoil beneath a cultivated crop and a permanent pasture. J. soil Sci. 44:451-458.

Welker, W.V. and D.M. Glenn. 1989. Sod proximity influences the growth and yield of young peach trees. J. Amer. Soc. Hort. Sci. 114:856-859.