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OF WATER TABLE MANAGEMENT

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By

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ABSTRACT

WATER QUALITY AND BIOMASS IMPACTS
OF WATER TABLE MANAGEMENT

By

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Research conducted in 1990 and 1991 evaluated the influences of water table management on (1) the fate of agricultural chemicals in drainage waters, and (2) corn biomass production. The treatments were "subirrigation" (SI), "subsurface drainage" (DO), and "no subsurface drainage" (ND). 1990 had above average seasonal rainfall, and the 1991 had below average seasonal rainfall.

NO_3-N drainage loadings from the SI and DO treatments increased compared to the ND treatment for both growing seasons. The SI treatment reduced NO_3-N loadings compared to the DO treatment for both growing seasons. PO_4-P drainage loadings from the SI and DO treatments were reduced compared to the ND treatment for above average rainfall. PO_4-P loadings from all three treatments were insignificant for below average rainfall.

Plant biomass increased in SI compared to DO and ND during above average rainfall. Plant biomass decreased in SI compared to DO, and increased compared to ND during below average rainfall.

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Water table management is defined as any practice which includes subsurface drainage, controlled subsurface drainage and/or subirrigation. Such practices provide a means of regulating the water table at optimum depths during periods of both drought and excessive rain. Optimum water table depths are those which provide sufficient amounts of water in the root zone of developing crops in order to satisfy the water requirements. Artificial drainage removes excessive water from the root zone during periods of heavy rainfall providing a suitable environment for developing crops. Drainage also ensures trafficable conditions for field operations. Water table management has been shown to be economically beneficial to Michigan corn and sugar beet producers (LeCureux and Boom, 1989a&b).

Controlled drainage/subirrigation systems provide a means of water management for agricultural lands that require both irrigation and drainage for crop production. During drought periods, water is supplied through the drainage system to the root zone of the growing crop. Controlling drainage also allows for the conservation of water added to the field by rainfall. The system operates as a drainage system to remove excessive water from the root zone during wet periods.

There is public concern over the environmental fate of agricultural chemicals in drainage water. Excessive losses of nutrient and pesticides in drainage are detrimental to the quality of receiving surface water bodies, and adversely affect the surrounding ecology. In addition, mismanagement of agricultural chemicals is a loss of resources. There are many examples in the United States and worldwide of the adverse impacts drainage pollution has on surface and groundwater quality.

In the United States, over 30 million hectares of cropland benefit from artificial drainage, with 75 percent in need of drainage system improvement or replacement (USDA, 1987). Along the Atlantic Coastal regions, the improvement of surface and subsurface agricultural drainage has increased transport of commonly used fertilizer nutrients to adjacent receiving waters (Deal, et al., 1986) Of particular concern are the nitrogen and phosphorus nutrients. The nitrates threaten regional drinking water supplies, and the phosphorus threatens the delicate wetland wildlife.

On the Pacific Coast, the San Luis Drainage in The San Joaquin Valley of California is a large water drainage and distribution system which serves most of the agricultural lands and many municipalities in California. High salinity and nitrate contents are commonly found in groundwater beneath irrigated lands, and several chlorinated hydrocarbon pesticides have been detected in numerous wells (Schmidt, et al., 1987).

In the north central region, fertilizer use accounts for about 70% of the total annual usage in the United States (Keeney, 1985) and nitrate nitrogen concentrations have been found to exceed the 10 mg/l drinking water standard in many regional groundwater aquifers (Hallberg, 1986). Commonly used herbicides such as alachlor, atrazine, metolachlor and cyanazine have been found in groundwater of several states (Holden, 1986 and Ritter, 1986).

The European Community (EC) member nations have experienced an average increase in agricultural productivity per laborer of 7 percent per year over 20 years (Du Vivier, 1986). The EC agricultural policies have led to an intensification of production and increased land values, and the consequences have been increased fertilizer pollution, field drainage, and wildlife habitat destruction (World Resources, 1987). Funding has been made available to EC member nations for improving agricultural productivity through field drainage. For most of Europe, field drainage is modified or installed in existing agricultural land, but in France, much of the field drainage is for the conversion of wetlands (Baldock, 1984).

Within the former Soviet Union, the extent of pollution caused by fertilizer and pesticide runoff in agricultural drainage is staggering. Collective farming practiced in communist nations was often performed on a very large scale. An estimated billion and a half tons of fertile soil are lost to erosion each year, and indiscriminate use of pesticides and fertilizers have poisoned millions of acres of farmland (U.S. News & World Report, 1992). Thirty percent of all foods in the former Soviet Union contain pesticides considered hazardous and are banned in the United States and the European Community. The full extent of the pollution problem and its impacts are far from being realized in the former Soviet Union and other communist block nations since researchers have not until recently been able to investigate and report the full extent of damage caused by agricultural production, and agricultural irrigation and drainage practices.

In the United States, the primary nutrient pollutants of concern are nitrates and phosphorus. It was concluded that drinking water containing high nitrate concentrations had the potential of causing methemoglobinemia, a blood disorder in infants that results in adverse health affects and often death (Hammer, M.J., et al., 1981). The phosphorus anion orthophosphate contributes to algae and aquatic plant growth associated with eutrophication in surface waters. The maximum contaminant level for nitrate nitrogen set by the EPA for drinking water standards is 10 ppm, and a commonly established maximum concentration for orthophosphate phosphorus is 1.0 ppm (Viessman, W.J., et al., 1985). The phosphoric form of orthophosphate phosphorus is the stable form of phosphorus and provides a good starting point for investigating phosphorus reactions in soils (Lindsay, 1979).

The 1986 amendments to the Safe Drinking Water Act required that maximum contaminant levels of highly water-soluble pesticides be enforced within three years of enactment. Examples of such pesticides are alachlor, atrazine, simazine and carbofuran (Cook, 1989). The maximum contaminant levels proposed for alachlor, atrazine and carbofuran are 2, 3 and 40 ppb, respectively (Benson, 1989).

Michigan has 7.9 million acres of Class I through III cropland, and over 3 million acres requires drainage in order to be productive (USDA, 1982). Within a five county area near the Saginaw Bay of Lake Huron, over 1.6 million ha of land in Michigan has the potential to utilize water table management systems (Kittleson, et al., 1990). This has resulted in increased concern as to the potential impact these systems may have on the environment.

Scientists at Michigan State University have been conducting field research on the effects of subirrigation on nutrient and pesticide concentrations and loadings in discharge waters and soil water since April, 1987 (Protaswiewicz, et al., 1988).

The Unionville site, the subject of this thesis, is located in the thumb region of Michigan and within 1 km of the Saginaw

Bay. The water table management system was installed during the summer of 1989 by members of the Michigan Land Improvement Contractors Association. The 13.1 ha site is on soils representative of the soils and topography most likely to be subirrigated in Michigan and the North Central Region of the United States.

The objective of the Unionville Site project is to evaluate and demonstrate the influences of water table management practices on the environmental fate of agricultural chemicals, with emphasis on nitrogen and phosphorus, for a soil type with potential for subirrigation expansion. The effect of water table management practices on crop biomass production was also evaluated. The specific objectives are to:

> To compare the chemical concentrations and loadings in the soil and drainage waters, and compare the corn biomass production, corn leaf, stem and kernel nutrient content of a "subirrigation / controlled drainage" treatment, a "conventional subsurface drainage" treatment, and a "no subsurface drainage" treatment during growing seasons with both above and below average seasonal rainfall.

LITERATURE REVIEW

Nutrients

As stated previously, the main nutrient pollutants of concern are nitrates and the phosphorus anion orthophosphate.

Nitrogen is one of many components that are essential for plant growth processes. The amount of nitrogen in available forms for plants is small, while the annual requirements by crops is relatively large. Often excessive amounts of nitrogen in readily soluble forms are lost through drainage waters in high quantities creating the potential for surface and groundwater pollution. It can also be lost from the soil by volatilization.

The three major forms of nitrogen in mineral soils identified by Brady (1984) are organic nitrogen associated with the soil humus, ammonium nitrogen fixed by certain clay minerals, and soluble inorganic ammonium and nitrate compounds. Many complex transformations accompany the intake and loss of nitrogen in soils through the course of a year. These changes occur due to the interlocking succession biochemical reactions in what is known as the nitrogen cycle. Plants absorb most of their nitrogen in the ammonia or nitrate forms. Nitrate is usually the predominant source of nitrogen due to usual higher concentrations in the soil and its ability to freely move to the roots by mass flow and diffusion (Brady, 1984).

Much of the nitrogen in a soil is in organic combinations, is protected from loss and is mostly unavailable to plants. Nitrogen is tied up in organic forms by the process of immobilization. The slow release of nitrogen occurs with the conversion of organic to inorganic nitrogen through the process of mineralization. Both the organic and inorganic soil fractions can fix ammonia in forms relatively unavailable to plants and even microorganisms. Many different mechanisms and compounds are involved in the fixation process. Fixation occurs by clay minerals and organic matter.

Microorganisms in the soil cause the process of nitrification which is the enzymatic oxidation of ammonia to nitrates. Nitrification occurs at a rapid rate under warm temperature, aerated soil, and moist conditions. Nitrate nitrogen, whether added by fertilizers of formed by nitrification, has four possible fates (Brady, 1984). It may (1) be incorporated into microorganisms, (2) assimilated into plants, (3) lost to drainage, and (4) escape in a gaseous state.

In poorly drained soils with low aeration, nitrates are subjected to reduction by the process of denitrification. The reduction products include nitrogen gases which can be lost to the atmosphere. This reduction occurs primarily through microbial action, although some chemical reduction occurs.

Phosphorus is as critical in agricultural crop production as nitrogen. In soils, both inorganic and organic forms of phosphorus occur and both are important to plants. The amount of phosphorus available for plant use at any given time is very low, seldom exceeding 0.01% of the total phosphorus in the soil (Brady, 1984). The requirements of the plants are supplemented through fertilizing, but much of what is applied is converted to the less available inorganic forms. In the inorganic form, phosphorus is released very slowly and is usable to plants over a period of years.

The retention of phosphorus is viewed as a continuous sequence of precipitation, chemisorption, and adsorption. With phosphorus generally remaining at low concentrations in the soil, adsorption appears to be the dominant retention mechanism (Tisdale, et al., 1985). Precipitation of many reaction products often occurs with the addition of common phosphoric fertilizers. Due to the variety of chemical properties of fertilizer salts and their mixtures, a great diversity of compounds in soil systems is to be anticipated (Tisdale, et al., 1985). Phosphorus held at the surface of a solid is said to be adsorbed. When phosphorus penetrates more or less uniformly into the solid phase, it is considered to be absorbed or chemisorbed (Tisdale, et al., 1985).

Potassium is another vital plant nutrient. Potassium activates numerous enzymes that are responsible for such plant processes as energy metabolism, starch synthesis, nitrate reduction, and sugar degradation. Most mineral soils are relatively high in total potassium. But the quantity of potassium held in an easily exchangeable condition at any given time is usually very small.

Most of potassium is held rigidly as part of the primary minerals or is in fixed forms that are moderately available to plants (Brady, 1984). Factors that affect the amount of potassium fixed include (a) the nature of the soil colloids, (b) wetting and drying, (c) freezing and thawing, and (d) the presence of excess lime. Annual losses of available potassium by leaching and erosion are much higher than those of nitrogen and phosphorus.

Water Table Management

Effect on Field Runoff

Subsurface Drainage

The effects of subsurface drainage on field runoff show that subsurface drainage reduces overland flow from fields as compared to similar fields that do not have subsurface drainage. However, the overall water that leaves fields is increased. The predominant flow to the edge of field from a subsurface drainage system is in subsurface drain flow. But subsurface drainage system design, climatological, geographical and soil conditions were all found to influence the rate of flow from a field.

Willard, et al. (1927), Schwab and Fouss (1967) Schwab, et al. (1977), Bengtson, et al. (1984 & 1988), Istok and Kling (1983), Jacobs and Gilliam (1985), Bottcher, et al. (1981), Skaggs, et al. (1982), and Evans and Skaggs (1989) reported that overland flow was reduced by subsurface drainage compared to fields with no subsurface drainage. However, these same studies along with Schwab, et al. (1980) reported that the overall drainage to edge of field was increased by subsurface drainage, and that more water is removed from a field or treatment by subsurface drains than by surface drains. This observation was also reported by Natho-Jina, et al. (1987), Jackson, et al. (1973), Evans, et al. (1984), and Fouss, et al. (1987). Only Gambrell, et al. (1975) reported higher surface drainage volumes than subsurface drainage volumes from a field.

Controlled Drainage and Subirrigation

Controlled subsurface drainage and subirrigation has been shown to reduce total subsurface drain flow of conventional subsurface drained fields. The effectiveness of controlling overland flow by controlled drainage and subirrigation systems was dependent upon field characteristics and climatological factors. Research on the effects of controlled subsurface drainage and subirrigation have on field runoff is recent and the data is limited.

Campbell, et al. (1985), Gilliam and Skaggs (1986), Deal, et al. (1986), Fouss, et al. (1987), and Evans and Skaggs (1989) reported that controlled drainage and subirrigation system design and management has a significant impact on the drainage flow from agricultural fields. Campbell, et al. (1985) reported a decrease in surface drainage to edge of field from a subirrigation system compared to a water furrow system, but that the total drainage was increased by the subirrigation system. Gilliam and Skaggs (1986), and Deal, et al. (1986) both reported that controlled drainage compared to conventional subsurface drainage increased surface drainage to edge of field but that the total drainage was reduced. Fouss, et al. (1987) also reported that controlled drainage reduced the total drainage to edge of field compared to conventional subsurface drainage. Evans and Skaggs (1989) reported that total drainage to edge of field was reduced by controlled drainage compared to conventional subsurface drainage, but system design and management of controlled drainage affected the amount of surface drainage to edge of field.

Effect on Pollutants

Subsurface Drainage

Subsurface drainage reduces erosion and sediment bound nutrient losses, mainly phosphorus and potassium, by primarily reducing overland flow. Nitrogen losses, particularly nitrate-nitrogen, were generally increased in both overland and subsurface drain flow of subsurface drained fields compared to non drained fields, but system design and field characteristics influence greatly the fate of nitrate-nitrogen transport. Pesticide losses have been cited to be decreased with subsurface drainage, but there is very little data reported to be able to support any firm conclusions on the effect subsurface drainage has on the transport of pesticides.

In the Istok and Kling (1983) study on the effects subsurface drainage had on overland flow from a watershed, the effects on suspended-sediment loads transported to the edge of field were simultaneously studied. The principle soil series within the watershed is Willakenzie silt loam, a member of the fine-silty mixed mesic Ultic Haploxeralfs. These soils are moderately deep well-drained deposit of silty material overlying either a palesol or weathered tuffaceous sandstone. The watershed had no subsurface drainage for the first two years of the study, and then was subsurface drained the last two years of the study.

A reduction in watershed (overland) sediment loss of approximately 55% was observed on the watershed after the subsurface drainage system was installed. The authors concluded that the reduction in sediment loss was caused by the reduction of watershed runoff observed in the study.

The Schwab, Nolte and Brehm (1977) study of the effects subsurface drainage had on total flow from a field also studied the effects on sediment transport (erosion) from a field. Three treatments compared were no subsurface drainage, subsurface drainage only, and combination surface and subsurface drainage. The treatments were located in a predominantly Toledo silty clay lakebed soil.

The no subsurface drained treatment had annual average sediment transport to edge of field of 3687 kg/ha. The subsurface drained only treatment had annual average sediment transport to edge of field of 2539 kg/ha. The combination treatment had annual average sediment transport to edge of field of 2672 kg/ha. The authors concluded that subsurface drainage reduced soil transport due to the reduction in overland flow measured.

Skaggs, Nassehzadeh-Tabrizi and Foster (1982) coupled the drainage simulation model DRAINMOD with the CREAMS model for simulating erosion and evaluating the effects of combination subsurface/surface drainage systems on erosion. The simulations were performed on a Goldsboro sandy loam (fine-loamy, siliceous, thermic Aquic Paleudults).

Changing the drainage system from one with good surface drainage and poor subsurface drainage to one with poor surface drainage and good subsurface drainage caused predicted average annual rates of erosion to be reduced from 9 to 0.9 metric tons/ha. Increasing the subsurface drain depth from 0.75 m to

1.25 m for a drain spacing of 30 m reduced predicted erosion over a 5-year period from 33 to 23 metric tons/ha. The authors concluded that the reduction overland flow observed had reduced erosion.

Schwab, Fausey and Kopcak (1980) studied the effects subsurface drainage has on sediment, nitrate-nitrogen, phosphorus and potassium transport to edge of field from the same three drainage treatments used to study the effects on flow.

The no subsurface drainage treatment had annual average sediment losses of 2548 kg/ha. The deep subsurface drainage only treatment had annual average sediment loss of 1529 kg/ha.

The no subsurface drainage treatment had an annual average nitrate-nitrogen carried to edge of field of 12.1 kg/ha with annual mean concentrations of 3.4 ppm ranging from 0.4 to 11 ppm. The deep subsurface drainage only treatment annual average nitrate-nitrogen carried to edge of field of 18.7 kg/ha, with annual mean concentrations of 8.2 ppm ranging from 5.0 to 23.0 ppm.

The annual average phosphorus carried to the edge of field from the no subsurface drainage treatment was 2.2 kg/ha, with annual mean concentrations of 0.9 ppm ranging from 0.4 to 2.0 ppm. The deep subsurface drainage only treatment had annual average of phosphorus carried to edge of field of 1.2 kg/ha, with annual mean concentrations of 0.7 ppm ranging from 0.5 to 1.0 ppm.

The annual average potassium carried to edge of field from the surface drainage only treatment was 31.6 kg/ha, with annual mean concentrations of 22.0 ppm ranging from 6.0 to 34.0 ppm. The deep subsurface drainage only treatment had annual average potassium carried to edge of field of 22.5 kg/ha, with annual mean concentrations of 14.2 ppm ranging from 3.0 to 26.0 ppm. The authors concluded that subsurface drainage caused a decrease in sediment, phosphorus, and potassium carried to edge of field, while nitrate-nitrogen was increased.

In the Bengtson, Carter, Morris and Bartkiewicz (1988) study of subsurface drainage effects on flow to edge of field, the effects on sediment, nitrogen and phosphorus carried to edge of field were also studied.

The annual average total soil carried to edge of field from the treatment without subsurface drains and the treatment with subsurface drains was 4986 and 3482 kg/ha, respectively. Of the 3482 kg/ha of total soil carried from the subsurface drain treatment, 3117 kg/ha was from overland flow and 365 kg/ha was from subsurface drain flow.

The annual average total ammonia and nitrate-nitrogen (total nitrogen) carried to edge of field from the treatment without subsurface drains and the treatment with subsurface drains was 7.3 and 6.0 kg/ha, respectively. Of the 6.0 kg/ha of total nitrogen carried to edge of field from the subsurface drain treatment, 4.2 kg/ha was from overland flow and 1.8 kg/ha was from subsurface drain flow.

The annual average total phosphorus carried to edge of field from the treatment without subsurface drains and the treatment with subsurface drains was 7.8 and 5.0 kg/ha, respectively. Of the 5.0 kg/ha of total phosphorus loss from the subsurface drain treatment, 4.7 kg/ha was from overland flow and 0.3 kg/ha was from subsurface drain flow.

The authors concluded that sediment loss was reduced by subsurface drainage primarily due to reduced overland flow. It was thought that nitrogen transport was restricted by a dense clay layer in the top meter of the soil profile, typical of the local Mississippi flood plain and reduced nitrogen carried to edge of field from the subsurface drained plots. Phosphorus losses were observed to be influenced mainly by time after application of phosphorus fertilizer, monthly amount of sediment loss, rainfall amounts, amount of surface runoff and drainage discharge.

Bottcher, Monke and Huggins (1981) studied the effects subsurface drainage had on sediment, nutrient and pesticide transport to edge of field from the 17 ha subsurface drainage system used to study the effects of subsurface drainage on flow to edge of field.

The annual average sediment carried to edge of field from the subsurface drained treatment was 94 kg/ha. Annual average total phosphorus and nitrate-nitrogen carried to edge of field were 0.2 and 6.5 kg/ha, respectively. Annual mean phosphorus and nitrate-nitrogen concentrations of 0.28 and 7.5 ppm, respectively.

The authors concluded through comparing the subsurface drained treatment to a more normal situation with partial subsurface drainage and greater overland flow, the total sediment losses and sediment-bound nutrient loadings were substantially less, but no data of the more normal drainage treatment was presented. Nitrate-nitrogen and other soluble nutrients were higher in the overland flow of the subsurface drained treatment. Overland flow had a direct impact on sediment and sediment bound nutrient loadings.

The Jacobs and Gilliam (1985) study of the effects subsurface drainage had on flow from field also studied the fate of nitrogen carried by drainage flow through examining measured nitrate concentrations in shallow groundwater beneath cultivated fields and in the overland drain flow from those fields. Nitrate-nitrogen losses in subsurface drain flow and overland flow were estimated using DRAINMOD for a Middle

Coastal Plain watershed.

The natural stream and no improved drainage treatment fields had mean nitrate-nitrogen concentrations in subsurface wells of 7.6 ppm (mg/l). The mean nitrate-nitrogen concentration in the overland flow at the edge of the fields was measured to be 1.1 ppm. The estimated annual nitrate-nitrogen carried by overland flow at the edge of the fields was 1.0 kg/ha.

The surface ditch treatment had a measured mean nitrate-nitrogen concentration from subsurface wells of 7.7 ppm and an estimated annual 9.9 kg/ha carried in subsurface flow. The mean nitrate-nitrogen concentration measured in overland flow at the edge of the field was 1.7 ppm and an estimated annual 3.8 kg/ha carried in overland flow.

The subsurface drain treatment had a mean nitrate-nitrogen concentration measured from the subsurface drain flow of 14.8 ppm with an estimated annual 54.9 kg/ha carried in subsurface drain flow. The mean nitrate-nitrogen measured from overland flow at the edge of the field was 1.2 ppm with an estimated annual 0.3 kg/ha carried in overland flow.

The authors concluded that subsurface drainage caused more nitrate-nitrogen to be carried to edge of field. The highest amounts were carried in subsurface drain flow. Subsurface drainage caused a reduction in nitrate-nitrogen carried in overland flow.

In the Jackson, Asmussen, Hauser and White (1973) study, nitrate-nitrogen carried to edge of field was monitored in both the overland and subsurface drain flow from a subsurface drainage system. Water samples from both overland flow and subsurface drain flow were collected during each natural rainfall event that caused overland and subsurface drain flow. Water samples taken from the site before any agricultural practices were initiated showed appreciable nitrate-nitrogen concentration.

The total annual average nitrate-nitrogen carried to edge of field was 43.64 kg/ha, with 0.30 kg/ha by overland flow and 34.34 kg/ha by subsurface drain flow. The authors concluded that the high proportion of nitrate-nitrogen carried in the subsurface drain flow can be accounted for by the high leaching potential of the sandy soil.

Baker, Campbell, Johnson and Hanaway (1975) made measurements of nitrate-nitrogen, sulfate, orthophosphate, and total phosphorus concentrations and loads carried to edge of field from four subsurface drained plots 0.42, 0.46, 0.41 and 0.46 ha in size, at a study site in Iowa from 1970 to 1973. The soil type was a silty loam with a maximum slope of 2%.

Average subsurface flow for all four plots was measured on a daily basis for the individual flow periods. The average daily flow ranged from 0.05 to 2.62 mm/day. The annual average nitrate-nitrogen carried to edge of field by subsurface drain flow was 30.6 kg/ha. The mean nitrate-nitrogen concentration in subsurface drain water for individual flow periods was 21.0 ppm, ranging from 8.2 to 36.2 ppm.

The annual average orthophosphate carried to edge of field by subsurface drain flow was 0.003 kg/ha. The mean orthophosphate concentration in subsurface drain water for individual flow periods was 5 ppm, ranging from 2 to 13 ppm. The annual average total phosphorus carried to edge of field by subsurface drain flow was 0.018 kg/ha. The mean total phosphorus concentration in subsurface drain water for individual flow periods was 24 ppm, ranging from 16 to 103 ppm.

The authors concluded that nitrate-nitrogen concentrations increased with increased flow to end of field from rain events. But similar intensity events did not yield similar amount of nitrate-nitrogen. This was accounted for by differences of nitrate-nitrogen concentrations in the water that passed through the soil profile, soil moisture conditions, depth and amount of organic matter, temperature, tillage, and timing and amounts of fertilizer applied.

Willardson, Meek, Grass, Dickey and Bailey (1972) studied the process of denitrification in an agricultural field by the submergence of drains in the San Joaquin Valley of California. The soil around the subsurface drains, groundwater from the center of the experimental field, and subsurface drainage flow were tested for nitrate-nitrogen concentrations.

The highest nitrate-nitrogen readings ranging from 330 to 364 ppm were found in the soil around the bottom of the subsurface drains while the soil at the top of the drains had lower readings ranging from 10 to 218 ppm. The highest concentrations found in all measurements were around the drains. While nitrate-nitrogen concentrations remained the same over a measured period of time, subsurface drain flow concentrations decreased over the same period. From this data, the authors concluded that denitrification was occurring.

Benoit, Grant, Bornstein and Hepler (1989) measured concentrations of carbon and nitrogen in subsurface drain flow from different subsurface drainage plots to study the long-term changes in soil carbon and nitrogen, and determine nitrogen levels in soil water and subsurface drain flow. Each plot was 36 x 36 m (118 x 118 ft) and located on a poorly drained silty clay loam soil in Maine. Measurements were made from 1978 through 1983. Three treatments were studied. The first treatment was three plots with subsurface drains spaced

3 m, the second treatment was three plots with subsurface drains spaced 6 m, the third treatment was three plots with subsurface drains spaced 12 m, and the forth treatment was three plots with no drains.

Data graphically presented showed that subsurface drainage caused a decrease in organic carbon and loss of nitrogen in the 0- to 0.15-m soil layer. Nitrate-nitrogen concentrations in subsurface drain flow averaged as high as 33 ppm (range of 29-36 ppm) for all drain spacings in July of 1980 but decreased to less than 1 ppm by November of 1984. The authors concluded that long term potential for nitrogen loss to overland or subsurface drain flow from drainage of these soils was small, and that proper management of cropping and fertilizer practices can keep the potential at minimum.

The model Kanwar, Johnson, and Baker (1983) developed to simulate the major water processes occurring in a typical agricultural watershed also simulated the nitrogen-transport processes.

The measured and predicted nitrogen carried by subsurface drain flow was 30.84 and 30.47 kg/ha. The model provided satisfactory simulation results. Differences between measured and predicted values were caused by lack of a completely accurate hydrologic predictions. The authors concluded that the processes of nitrification, mineralization, nitrogen uptake, and denitrification are areas that need to be better investigated for better representation.

Muir and Baker (1976) monitored the herbicides cyanazine, cyprazine, atrazine, and metribuzin which were applied separately to four subsurface drained experimental plots 1.75, 1.16, 1.30 and 0.60 ha in size, located in southern Quebec, Canada, from 1973 to 1974. Initial levels of atrazine and its degradation products were detected in subsurface drain flow from all four plots before pesticide applications were made. Atrazine had been used on a yearly base since 1968.

Atrazine concentrations from the subsurface drain water ranged from 0.30 to 1.49 ppb (μg/l), 0.00 to 0.68 ppb for cynazine, and 0.00 to 0.57 ppb for cyprazine. Metribuzin was applied during the second year and was found in the subsurface drain water in concentrations ranging from 0.00 to 1.65 ppb. Atrazine levels were consistently higher than all other herbicides because of residuals left from previous applications. Overall analysis showed that about 0.15% of the applied chemicals appeared in the subsurface drain water either in the unchanged form or as degradation products.

Southwick, et al. (1990) measured atrazine and metolachlor carried in subsurface drain flow over a period of 243 days. The herbicides were applied preemergent to corn grown on subsurface drained treatment plots, and on undrained treatment plots. The subsurface drainage treatment consisted of three 4 ha (9.9 ac) and, two 2 ha (4.9 ac) plots. The no subsurface drain treatment plots consisted of two 4 ha (9.9 ac) and, two 2 ha (4.9 ac) plots. The plots were located on a clay loam near Baton Rouge, Louisiana.

Atrazine was applied at a rate of 1.63 kg/ha, and a total of 0.00623 kg/ha was measured in subsurface drain flow. Metolachlor was applied at a rate of 2.16 kg/ha, and 0.02760 kg/ha was measured from subsurface drain flow. Concentrations for atrazine ranged from 0.015 ppb (243 days after application) to 3.53 ppb (12 days after application). Concentrations for metolachlor ranged from 1.92 ppb (58 days after application) to 29.3 ppb (12 days after application). All of the metolachlor carried in the subsurface drain water was observed within the first 59 days after application.

Bengtson, et al. (1990) reported on the amount of metolachlor and atrazine carried to edge of field from a subsurface drained treatment and in flow from the no subsurface drainage treatment over a 243 day period.

The total amount of atrazine and metolachlor measured in flow to edge of field from the subsurface drainage treatment was 0.02347 kg/ha and 0.02584 kg/ha, respectively. The total amount of atrazine and metolachlor measured in overland flow to end of field from the no subsurface drain treatment was

0.05164 kg/ha and 0.05268 kg/ha, respectively. Subsurface drainage reduced the amount of atrazine and metolachlor carried to end of field.

Smith, et al. (1990), reported on the movement of atrazine and alachlor within the soil profile and a shallow water table aquifer following surface application. Concentrations of atrazine in the soil water at a depth of 0.61 m reached 350 ppb 19 days after application, but no alachlor was detected in the soil below a depth of 0.36 m. Atrazine concentrations as high as 90 ppb were found in the shallow ground water six months after application while no alachlor was detected.

Protasiewicz, et al. (1988), reported to the Michigan Department of Natural Resources the results of a 1 year water quality pilot study from 1987 to 1988. Atrazine carried to the edge of field by the subsurface drain flow from the conventional subsurface drainage treatment was 0.00126 kg/ha. The maximum concentration of atrazine observed in the subsurface drain water was 0.8 ppb.

Controlled Drainage and Subirrigation

Properly designed and managed controlled drainage and subirrigation systems have the potential to reduce the transport of accumulative plant nutrients and applied herbicides. In addition to design and management factors, site characteristics influence the fate of transport of nutrients and applied herbicides. No data was provided on the sediment transport in controlled drainage and subirrigation systems and little has been reported on the fate of potassium transport.

Gilliam, Skaggs and Weed (1979) compared the amount of nitrate-nitrogen carried to edge of field from conventional drainage and controlled drainage treatments. Controlled drainage was maintained by using flashboard riser-type water level control structures installed at two locations representative of soil conditions of large areas of artificially drained soils of the North Carolina Coastal Plain, both well and poorly drained. Each location had 2 fields, one which was under conventional drainage while the other was under controlled drainage. The treatments of each field were changed periodically.

Nitrate-nitrogen reductions in subsurface drain flow from an average 32.5 to 4 kg/ha by controlling subsurface drainage in the moderately well drained soils was observed. The nitrate-nitrogen concentrations tended to be a constant 15-20 ppm year round. In the moderately well drained soils, there was no sign of increased denitrification.

The average total nitrate-nitrogen carried to edge of field from the conventional drainage treatments was 27.5 kg/ha and slightly half that was found at the edge of field for the controlled drainage treatments in the poorly drained soils. The authors concluded this reduction was due to increased water movement into and through deeper soil horizons which underwent denitrification. High water table control could have a long-term effect on structure in some soils but this phenomena was not studied.

The Campbell, Rogers, and Hensel (1985) study on flow to edge of field from a subsurface drainage-irrigation system with drainage control and a water furrow-irrigation system also studied nutrient transport to edge of field from both systems. Nitrate-nitrogen losses were the predominant nitrogen form detected from both systems, and orthophosphate was measured as well.

The total nitrate-nitrogen carried to edge of field from the water furrow system was 4.53 kg/ha. The total nitrate-nitrogen carried to edge of field was 2.75 kg/ha, with 0.83 kg/ha carried in overland flow and 1.91 kg/ha carried in subsurface drain flow.

The total orthophosphate carried to edge of field from the furrow system was 1.10. The total orthophosphate carried to edge of field was 0.43 kg/ha, with 0.26 kg/ha carried in overland flow and 0.17 kg/ha carried in subsurface drain flow.

The greater loss of nitrate-nitrogen in the water furrow system was unexpected by the researchers. The authors concluded that the combining of a controlled high water table and raised row-beds created conditions resulting in interflow through the row-beds to the alleys instead of leaching downward to the drains.

Gilliam and Skaggs (1986) determined the effects of drainage system design and management upon water quality of drainage water through use of the DRAINMOD computer model on two experimental Atlantic Coastal Plain soils. Nitrate-nitrogen loads carried to edge of field were compared between conventional drainage treatments and controlled drainage treatments.

The annual average nitrate-nitrogen carried to edge of field from the conventional drainage treatments was 33.5 kg/ha. The annual average nitrate-nitrogen carried to edge of field from the controlled drainage treatments was 22.8 kg/ha. The annual average phosphorus carried to edge of field from the conventional drainage treatments was 0.12 kg/ha. The annual average phosphorus carried to edge of field from the controlled drainage treatments was 0.22 kg/ha. Controlled drainage reduced the nitrate-nitrogen carried to edge of field but increased the phosphorus carried to edge of field.

Deal, Gilliam, Skaggs and Konyha (1986) used the DRAINMOD computer simulation to predict nutrient losses under various drainage designs from 6 different soils over a 20 year period. Nitrate-nitrogen and total phosphorus carried to edge of field from conventional drainage treatments and controlled drainage treatments were compared.

The predicted annual average nitrate-nitrogen carried to edge of field from the conventional drainage treatments was 19.30 kg/ha, with 1.42 kg/ha in overland flow and 17.88 kg/ha in subsurface drain flow. The predicted annual average nitrate-nitrogen carried to edge of field from the controlled drainage treatments was 14.49 kg/ha, with 1.93 kg/ha in overland flow and 12.56 kg/ha in subsurface drain flow.

The annual average total phosphorus carried to edge of field from the conventional drainage treatments was 8.30 kg/ha, with 1.60 kg/ha in overland flow and 6.70 kg/ha in subsurface drain flow. The annual average total phosphorus carried to edge of field from the controlled drainage treatments was 8.00 kg/hg, with 2.00 kg/ha in overland flow and 6.00 kg/ha in subsurface drain flow. Controlled drainage reduced nitrate-nitrogen and phosphorus carried to end of field, but increased both amounts carried to edge of field by overland flow.

Skaggs and Gilliam (1981) modified the computer simulation model, DRAINMOD to predict nitrate-nitrogen movement from artificially drained soils with high water tables. Conventional drainage, controlled drainage during the winter and controlled drainage all year were simulated for both good and poor surface drainage systems.

The good surface drainage system had predicted nitrate-nitrogen carried to edge of field from the conventional subsurface drainage treatment of 20.0 kg/ha. Nitrate-nitrogen carried to edge of field from the controlled drainage treatment was 14.5 kg/ha for controlled drainage during the winter, and 12.2 kg/ha for controlled drainage all year.

The poor surface drainage system had predicted nitrate-nitrogen carried to edge of field from the conventional drainage treatment of 38.9 kg/ha. Nitrate-nitrogen carried to edge of field from the controlled drainage treatment was 33.0 kg/ha for controlled drainage during the winter, and 39.0 kg/ha for controlled drainage all year.

The Evans and Skaggs (1989) study on the effects water table management strategies have on flow to edge of field also studied average annual nitrate-nitrogen and total phosphorus carried to edge of field. Subsurface drain and overland flow were compared between conventional and controlled drainage treatments.

The average annual nitrate-nitrogen carried to edge of field from the conventional drainage treatments was 35.0 kg/ha, with 8.5 kg/ha in overland flow and 26.5 kg/ha in subsurface drain

flow. The annual mean concentrations were 3.0 ppm in overland flow and 8.7 ppm in subsurface drain flow.
The average annual nitrate-nitrogen carried to edge of field from the controlled drainage treatments was 18.7 kg/ha, with 4.5 kg/ha in overland flow and 14.2 kg/ha in subsurface drain flow. The annual mean concentrations were 2.6 ppm in overland flow and 6.8 ppm in subsurface drain flow.

The average annual total phosphorus carried to edge of field from the conventional drainage treatments was 0.69 kg/ha, with 0.48 kg/ha in overland flow and 0.21 kg/ha in subsurface drain flow. The annual mean concentrations were 0.14 ppm in overland flow and 0.05 ppm in subsurface drain flow.

The average annual total phosphorus carried to edge of field from the controlled drainage treatments was 0.45 kg/ha, with 0.28 kg/ha in overland flow and 0.17 kg/ha in subsurface drain flow. The annual mean concentrations were 0.12 ppm in overland flow and 0.07 ppm in subsurface drain flow.

In the Protasiewicz, et al. (1988), report to the Michigan Department of Natural Resources, the total atrazine carried to the edge of field by the subsurface drain flow from the subirrigation treatment was 0.00277 kg/ha. The maximum concentration observed in the subsurface drain water was 1.8 ppb. The subsurface drain atrazine loading from the subirrigation treatment was 120% greater than from the conventional subsurface drainage treatment.

Effect on Groundwater Quality

Subsurface Drainage

Little published studies are available that look at the effects subsurface drainage practices have on groundwater quality. The cost of studying groundwater aquifers is high and studies are focused more on impacts to surface water quality. Only until recent growth in concern of groundwater aquifer contamination has created a demand to research the impacts of subsurface drainage on groundwater quality. Many of the studies cited describe the potential problems that exist under agricultural practices and the needs of investigating agricultural water management practices. But for most soils that are drained, a low permeable soil protects the deeper groundwater aquifers that are used by the public.

Schmidt and Sherman (1987) summarized numerous research findings on the effects of irrigation and on groundwater quality in California. The authors concluded that contamination of groundwater aquifers by nutrients and pesticides is dependent on the soil structure within a profile. The presence of sandy soils and shallow groundwater was found to contain the highest amounts of pesticides and nitrate levels. Where hardpans were present, no significant amounts of pesticides and nutrients used in agricultural production have been found.

Mossbarger and Yost (1989) reviewed available case studies from the Central Sand Plain of Wisconsin and discussed present and potential problems associated with irrigation and groundwater quality. These soils are characteristically low in moisture holding capacities where heavy irrigation and applications of herbicides and pesticides are practiced in order to achieve substantial crop yields. Because of the high hydraulic conductivities and leaching potential of sandy soils, shallow groundwater aquifers in these areas are extremely susceptible to contamination of soluble nutrients and pesticides.

Pivetz and Steenhuis (1989) investigated pesticides, nitrates and tracers carried to edge of field from subsurface drains and to the groundwater from 1987 to 1989, in northern New York. The site was located on a predominantly sandy clay loam and clay loam soil overlying a profile of clay on top of gravelly loam and sandy loam. The profile was on top of bedrock, 9 m deep. Potential of contamination of underlying groundwater aquifers was thought to be minimal.

The results from the non-refereed American Society of Agricultural Engineers paper so far have found no significant traces of pesticides in deep groundwater well samples. Nitrates were detected in deep groundwater well samples and exceeded the 10 ppm maximum contamination level on 2 occasions.

Users of chemicals should understand the factors that influence the movement of a chemical through a soil profile. The characteristics of the chemical, frequency of application, type of soil and depth of water table are crucial in preventing possible contamination of groundwater (Michigan State University, 1988).

Controlled Drainage/Subirrigation

Few published studies are available that look at the effects water table management practices have on groundwater quality.

Ritter, Humenik, and Skaggs (1990) reviewed the effects irrigated agricultural has on groundwater quality through out the northeastern and Appalachian states. The largest irrigated areas are located in North Carolina, New Jersey, New York, Delaware, Virginia, and Maryland, most of which is on Coastal Plain soils. These soils are typically sandy loam or loamy sand and are highly susceptible to leaching of soluble materials, especially after heavy rainfalls.

The authors cited the studies of water table management performed in North Carolina that have shown significant reduction in nitrate-nitrogen entering surface waters under controlled drainage. But little research has been performed to determine the fate of soluble materials, especially pes

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pesticides and nitrate-nitrogen through sandy soils into underlying groundwater aquifers.

Crop Yield

Carter, et al. (1988) found increased sugarcane yields under a subirrigation and controlled drainage system compared to a non-irrigated and surface drained only system. The benefits to sugarcane yield from water table management were most significant during periods of drought. Foust, et al. (1987) observed maximum corn silage yields from fields with controlled subsurface drainage during a growing season with below normal rainfall and minimum yields during above normal growing season rainfall. Evans and Skaggs (1989) emphasized that properly designed and operated water table management systems can significantly increase yields and production efficiency compared to conventional subsurface drainage and no subsurface drainage. Mismanaged controlled drainage and subirrigation systems can significantly reduce crop yield and quality.

Belcher (1990) reported that corn and soybean production is sensitive to mean water table depth and water table fluctuation. Research found that the best operation management for subirrigation of crops is to establish a water table depth immediately following seeding. The water table should be raised periodically for short time periods during the growing season. At crop maturity, the system should be put into the subsurface drainage mode and maintained until after harvest. It was found to be beneficial to repeat the water table management cycle the next spring.

Sipp, et al. (1984) reported in an unpublished paper that corn yields increased substantially under water table management compared to a non-drained and non-irrigated conditions. Rausch and Nelson (1984) reported in an unpublished paper that subirrigation increased alfalfa production during the months of July and August compared to non-irrigated treatments. Carter, et al. (1988) found and reported in an unpublished paper that water table depths maintained within 0.30 m of the surface adversely affected soybean, wheat, and corn yields, but did affect the quality of the crops.

Biomass

Publication of research on biomass production is limited to observed effects environmental and climatological stresses have on various crops, little was found that addressed water table management effects on biomass production. Wareing (1978) reported that leaf shape may be profoundly modified by environmental factors. Dry weight of the plant was used to measure the amount of organic material synthesized by the plant. The ability of a plant to synthesize new material is dependent upon its leaf area. The rate at which new material is assimilated increases proportionately with the rate at which a plant grows and increases leaf area. Elk, et al.

(1966) reported that any factor affecting the size of corn plants should affect the leaf area as well. The actual yield obtained from a crop depends on the effects various factors have on the crop throughout the growing season.

The water use of the corn crop varies with the stage of development (Sprague, 1977). Water loss early in the growing season is primarily from evaporation from the bare soil. As crop cover increases with leaf development, transpiration becomes an increasingly dominant factor. Sprague (1977) also reported that the stand height may affect the amount of water use by the plant. Low stands use low amounts of water. As the stand increases, water use increases rapidly, but with time the growing stand decreases its water use which is due to a peak and subsequent decrease in solar energy utilization in evapotransporation from the stand.

Ritter and Beer (1969) reported that flooding corn early in the season was more detrimental to grain yield than flooding late in the season. Lal and Taylor (1969) reported that intermittent flooding early in the growing season reduced corn yields compared to maintaining constant water tables of 0.15 to 0.30 m in depth. Damage to corn due to flooding or high water contents is probably caused by many factors including low oxygen or high carbon dioxide concentrations in the soil air, the plant's respiration rate at flooding, reduced nutrient uptake, and possible toxicity of chemicals produced reducing conditions.

Alvino and Zerbi (1986) found that at the vegetative and flowering stage, plants reached their maximum height with shallow water depths under both irrigated and rain conditions. Highest yields were obtained on shallow water table depths even though grain moisture content increased as well. Baser, et al. (1981) reported that corn had maximum growth at water table depth of 0.3 m compared to 0.15 and 0.48 m. Rattan and George (1969) compared constant and varying water table depths, at two levels of nitrogen and two levels of the micronutrients zinc and copper. Corn grain yields were reduced at water table depths of 0.15 and 0.30 m, and varying water table depths with occasional flooding early in the growing season reduced yields even more. Higher levels of N, Zn, and Cu increased yields under well drained conditions and at shallow water table depths of 0.15 and 0.30 m. The uptake of N and Zn by corn was reduced by high water table depths and flooding.

Follett, et al. (1974) found that corn shoot growth was at maximum with intermediate water table depths, and corn grain yields were lower at high and low water table depths compared to medium water table depths. Shoot growth decreased in high water tables due to poor aeration, and decreased in low water tables due to decreased water availability.

SITE DESCRIPTION

The Unionville site is located in Tuscola County (S. 1/2 of N. 1/2 of S.W. 1/4 of Section 22, T.15 N. R.8 E). The Unionville research field is divided into three different treatment plots as shown in Figure 1. The 3.4 ha "subirrigation / controlled drainage" treatment (SI) and the 4.3 ha "conventional subsurface drainage" treatment (DO) have subsurface tile drains spaced at 4.6 m at a depth of 0.8 m. The "no subsurface drainage" treatment (ND) is 5.4 ha in size. Each plot has a shallow surface drain providing good surface drainage. A dike was built at the perimeter of each plot. The site has three soil types that are identified on Figure 1. They are: 1) Tappan loam, 2) Thomas muck, and 3) Essexville loamy sand. The results of a soil textural analysis performed at Michigan State University are presented in Table 1.

The Tappan loam soil is a fine-loamy, mixed calcareous, mesic Typic Haplaquolls (Soil Survey, 1980). The Thomas muck soil is a fine-loamy, mixed calcareous, mesic Histic Humaquept (Soil Survey, 1980). The Tappan and Thomas soils are poorly or very poorly drained. Surface water drainage is very slow to ponded with slow to moderately slow permeability. The Essexville loamy sand soil is a sandy over loamy, mixed calcareous, mesic Typic Haplaquoll (Soil Survey, 1980). Essexville soils are poorly drained, with rapidly permeable in the upper part and moderately slowly permeable in the lower part.

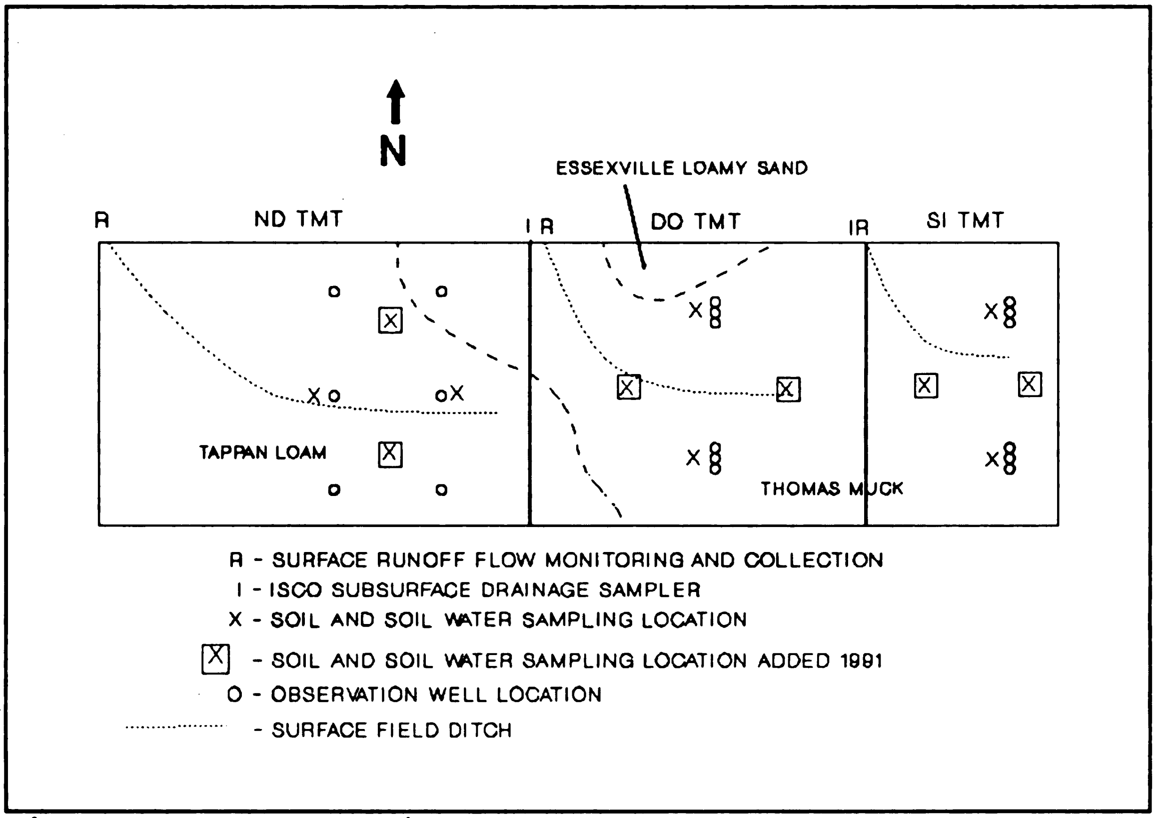

Figure 1. Research Site Layout

METHODOLOGY

System Operation and Data Collection

Water table, surface and subsurface tile outflow and rainfall were monitored using the bubbler system technique (Goebel, et al. 1985). A flow chart of the system used at the Unionville site is given in Appendix A. Water table depths and flow depths are measured using a datalogger that converts an analog signal from 7 pressure transducers which monitor pressure displacement caused by the depth of water in an observation well, flume well or orifice meter well.

The automated bubbler system was installed October 29, 1989. Actual monitoring of tile drain outflow, surface drainage and

Table 1. Soil texture and classification

Soil Layer	Depth, m	Sand	Silt	Clay	Texture
Ap (SI Zone)	0.00-0.30	67	25	8	Sandy loam
Ap (DO Zone)	0.00-0.30	69	22	9	Sandy Loam
Ap (ND Zone)	0.00-0.30	79	14	7	Loamy Sand
Bg (SI,DO,ND)	0.30-0.51	45	34	21	Loam
Bw (SI,DO,ND)	0.51-0.81	45	32	23	Loam

water table depth began on May 24, 1990. Frequent electrical and phone problems effecting data collection were solved in early June, 1990. For the 1991 growing season monitoring began on May 1, 1991 and the system ran virtually continuous without any major problems through out the growing season. In-line orifice meters (Protaswiewicz, et al., 1987) were designed, built and calibrated prior to their installation in the summer of 1989. The equation used to model flow through an in-line orifice meter under full pipe flow is taken from Sterns (1951) and has the form:

$$W-2.086*(d_2)^2*K*(p*H)^{1/2} \quad (1)$$

where: W = flow rate, l/min
d_2= Diameter of orifice, cm
K = Orifice Discharge Coefficient (dimensionless)
p = density of fluid, g/cm^3

The SI and DO treatment areas each have a separate main from which outflow is monitored and water samples collected. Location of water samplers both for surface and tile drains, soil and soil water sampling locations, and observation well locations are shown in Figure 1. At the beginning of the 1990 growing season, grab samples of the tile water were collected from the SI and DO treatment headstands until the bubbler system was fully functional in June, 1990, after which all samples were taken based on cumulative flow volumes using Isco Model 1600 automatic water samplers.

Meteorological Data

An on site LiCor 1200 weather station monitors daily average temperature, daily minimum and maximum air temperatures, daily soil temperature, daily rainfall, and daily net solar radiation. Data is downloaded from the data logger to a Radio Shack PC-100 on a monthly basis. Rainfall was also monitored in each of the three treatments using the bubbler system.

Water Table Elevation Data

The SI and DO treatments each have 6 water table observation wells installed as shown in Figure 1. The 6 wells are in two sets of three as follows: a well is 1 m from a tile drain lateral, another is located midway between two tile drain laterals (2.3 m), and the third is located in between the first two wells (1.6 m). The ND treatment has 6 observation wells through out the treatment plot as shown in Figure 1. All wells are placed to a depth of 1.5m, approximately 0.7m below tile depth. The observation wells are made of 2.54 cm diameter galvanized steel pipe.

Drainage Flow Monitoring and Water Sample Collection

The orifice meters measure flow rates which are used to obtain proportional flow based tile water samples. The bubbler system monitors the depth of water by measuring the water pressure from the piezometer tubes of the orifice meter. The software calculates and accumulates the flow using equation (1). The Isco samplers are linked to the datalogger and computer that monitor orifice flow measurements. The software signals the datalogger to activate the Isco samplers every 19000 l of accumulated flow. From August 8, 1990, through the remainder of the 1990 growing season, the control software was changed to take a tile drain sample every 57000 l of flow because of frequent heavy rains.

The water samples are stored in bottles within a insulated container of the Isco sampler. The Isco samplers are stored in an insulated box. Water samples were usually retrieved twice a week, and occasionally just once a week. The samples were transported in an ice chest and frozen when brought to the Michigan State University campus.

During June of 1991 it was noticed that bubbler lines used to monitor both orifice meters had been damaged by spring field work. This resulted in erroneous measurements of flow. A similar problem occurred for a few days in July when a backhoe crimped some of the orifice meter bubbler lines. Before repairing the lines in both cases, calibrations were made on the damaged lines and the erroneous flow data was corrected.

Two flumes were installed at the outlet of the surface drains of each treatment. Location of the flumes are indicated in Figure 1. The flumes were each calibrated in a laboratory at Michigan State University to obtain an exponential correlation of depth and volume of flow of water through the flume (Pruden and Fogiel, 1990). For both growing seasons, the non-linear regressions among the six flumes were almost the same and all yielded R^2 greater than or equal to 0.99. The equation used to calculate flow rate through the flumes for both the 1990 and 1991 growing season has the form:

$$y = (0.009 * (x^{2.036}) + 0.8) * 0.003785 \qquad (2)$$

where: x = Depth of Flow, mm
y = Flow Rate, m^3/min

In the field, depth of flow was monitored using the bubbler system. Field calibrations of depth of flow for each flume was conducted at least once a month during the growing season.

During the 1990 growing season, samples of the surface drainage water were collected using Coshocton wheels. The wheels were calibrated at Michigan State University. The wheels collected approximately 2% of the total surface outflow, and the composite sample was stored in a galvanized steel tank which was placed in an excavated pit.

Many problems occurred with the Coshocton wheels and galvanized steel tanks due to the heavy rains of August and September of 1990. The pit in which the tanks were placed often flooded and caused displacement of the tanks and/or collapse of the pit. Sediment build up in the Coshocton wheel frequently clogged the line running to the storage tank. The sample collector completely failed for one of the flumes in the SI treatment, so that flume was raised in order to force all surface outflow through the other flume. Heavy rains on September 6 and 7, 1990, washed out the flumes from the SI and ND treatment surface drainage collection sites, and no data was collected for this event from all three treatments. In August, 1990, a bubbler line for a flume in the ND treatment failed.

In September, 1990, a bubbler line for a flume in the DO treatment failed. In October 1990, heavy rains made it impossible to keep the flumes in place for all three treatments, and the surface outflow data was too incomplete to be reported for that month. However, grab samples were obtained from glass jar containers that were set in the surface ditch for all three treatments. All surface outflow reported from the ND treatment in August and September was estimated by calculating the outflow measured through the second operational flume and doubling the value.

For the 1991 growing season, an air pressure activated pumping system was built and installed for sampling water directly from the surface outflow of each treatment. The bubbler system in place at the site was modified to turn on the surface outflow pumps by sending 10 psi of pressure through an air line after 77 L of flow were measured through the flumes. A composite sample was collected and stored in the same galvanized tanks. Continuous flume data and samples were collected during 1991.

For both growing seasons, samples in the tanks were retrieved and put into frozen storage at the Michigan State University campus within 24 hours of the rain event.

Soil and Soil Water Collection

Soil samples during 1990 and 1991 were collected monthly except in May (after fertilizer application) and June when they were collected twice a month. The samples were collected using a hand bucket auger. Samples were obtained to 0.9m depth at 0.3m intervals. Each treatment was split into two replications (Figure 1) for the 1990 growing season. Within each replication, five different samples from the same depth were composite into one sample. For the 1991 growing season, two more replications were added to each treatment (Figure 1) from which a composited sample was taken from each depth. Care was taken to not allow top soil to fall within the sample hole in order to prevent contamination of underlying sample depths. An approximately equal portion (about two handfuls)

from each depth was collected for composite samples. The holes were backfilled after sampling.

Soil samples were stored in an ice chest during the time of sampling. The samples were immediately frozen if analysis was not going to be performed within 24 hours of collection.

Suction lysimeters were installed for 1990 and 1991 to collect soil water samples. Lysimeters were installed at the soil sampling locations (Figure 1), and soil water samples were obtained to 0.9m depth at 0.3m intervals. Soil water samples were taken during soil sampling. The lysimeters were pumped of any standing water, 70 psi of vacuum was applied, and the soil water sample was pumped from the lysimeter within 24 hours. In order for proper extraction of water from the soil, there must be a good interface established between the suction lysimeter porous ceramic cup and the soil. In 1990, the lysimeters were not properly installed in accordance with the soil environment and very few samples were collected. In 1991, the lack of significant rainfall events early in the growing season caused severe soil cracking around the lysimeters and prevented the development of a good interface between the lysimeter and soil. The soil water samples collected in 1990 and 1991 did not provide enough data to make comparisons from which to draw conclusions from among the three treatments.

Rain water samples were collected by attaching a funnel to a glass jar and mounting the jar onto a post. Samples were retrieved within 24 hours of the rain event, transported in an ice chest, and frozen immediately upon return to the Michigan State University campus. Grab samples of irrigation water were obtained from the SI treatment irrigation supply pipe and transported and stored the same way the rain samples were.

All soil and water samples were analyzed for nitrate nitrogen, orthophosphate phosphorus, and potassium for the 1990 and 1991 growing seasons. Ammonia nitrogen analysis was performed on soil and water samples collected during the 1991 growing season. Analysis was performed at the Michigan State University Soil Test Laboratory using methods approved by the United States Environmental Protection Agency (EPA).

Nitrate nitrogen analysis for both soil and water samples was performed using EPA method 353.2 (1989). Ammonia nitrogen analysis for both soil and water samples was performed using the Salicylate method. Phosphorus concentrations from soil extracts were obtained by Method 24-5.1 described by Summers (1986). The flow injection method described by Murphy, et al. (1986) was used to obtain phosphorus concentrations from water samples. Potassium concentrations were obtained by the auto-analyzer method/exchangeable potassium procedure for both soil extract samples and water samples approved by the United States Environmental Protection Agency (1989).

All water sample nutrient content results were expressed in mg/l (ppm). Loadings for both subsurface drain and surface drain samples were calculated by determining the total cumulated flow that occurred over the period between the taking of two water samples that were analyzed for nutrients. The concentration of the nutrients found in the water sample were multiplied by the cumulative flow from the unit area of the treatment.

The soil nitrate nitrogen and ammonia nitrogen analysis results were expressed in concentrations, and the orthophosphate phosphorus and potassium results were expressed in loadings per acre furrow slice. The furrow slice was assumed to be approximately 16.9 cm. The soil samples collected in the field are obtained from a 30.48 cm slice, so the results were adjusted to the actual sampling slice.

Alachlor analysis in soil samples were performed at the Michigan State University Pesticide Research Lab. Analysis on water samples were conducted at Heidelberg College in Tiffin, Ohio using pesticide immunoassay screens. These screens confirm the absence of pesticides above the method detection limit. If pesticides are detected, follow up analysis is performed to determine specific alachlor concentrations within a 0.2 ug/l (ppb) detection limit. Both alachlor methods are approved by the Environmental Protection Agency (1989).

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Agronomic Data

Plant leaf area and stem volume measurements were conducted at different plant growth stages on selected plants from each treatment for both growing seasons. Two plant growth stages were measured in 1990, and three were measured in 1991. For both growing seasons, the SI and DO treatments were split into north and south replications and had 35 randomly selected plants monitored in each replication. In 1990, the ND was split in east and west replications and had 35 randomly selected plants monitored in each replication. In 1991, the ND was split into north and south replications.

The stem volume was determined by measuring the minimum and maximum diameter of the base of the corn stalk using a caliper, and recording the height of the last unfurled corn leaf collar. The formula for the stem volume is as follows:

$$StemVol. = [(Stemn + Stemx)/20]^2 * 3.14/4 * Stemh \quad (3)$$

where: Stem Vol. = Computed Stem Volume, cm^3
Stemn = Minimum Stem Diameter, mm
Stemx = Maximum Stem Diameter, mm
Stemh = Height of stem, cm

Stem volume was converted to above ground plant biomass for the respective 1990 and 1991 growing seasons by the equations:

$$y = -1.41 + 0.18 * x \quad (4)$$

$$y = 287.24 + 0.07 * x \quad (5)$$

where: x = Stalk Volume, cm^3/m^2
y = Above ground plant biomass, g/m^3

The linear regression graphs and analysis from which equations

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(4) and (5) were computed are presented in Appendix H. Leaf index was computed by dividing the total leaf area of a treatment by the area of the treatment with units m^2/m^2.

Nutrient analysis was performed on plants randomly selected from each treatment. In 1990, ten plants were composited into two samples from each treatment on July 25 and August 8, and analyzed for nutrient content. On August 8, 1990, 10 ears of corn were randomly picked from each replication within each treatment and composited into a sample for nutrient content analysis. In 1991, ten plants were picked from each replication within each treatment and composited into two samples for analysis. Plant samples were collected on July 11, July 25, and September 4, 1991. The ears of corn from the plants picked on September 4, 1991, were also composited into two samples from each replication and analyzed for nutrient content.

Plant and kernel nutrient analysis were performed at the Michigan State University Soil Test Laboratory using Environmental Protection Agency (1989) approved methods. The analysis results were expressed in terms of percent nitrogen, phosphorus and potassium. The actual amount is calculated by multiplying that percentage by the mass of sample collected.

For the 1990 and 1991 growing seasons, Pioneer 375L variety corn was planted at 69,300 seeds/ha. Planting was performed on May 8,

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on May 8, 1990, and on May 21, 1991, respectively. Fertilizer and herbicides application rates and dates for both growing seasons are presented in Table 2. The yield goal for fertilizer application was 2.7 metric tons/ha for both growing seasons. The fertilizers were broadcasted preemergence both growing seasons.

Table 2. Fertilizer and herbicide summary

Type		Rate 1990 Growing Season:	1991 Growing Season:
Fertilizer, kg/ha:			
	Date Applied	5/8/90	5/21/91
	Total Nitrogen	214	198
	Total Phosphorus	101	77
	Total Potassium	168	118
Herbicides, L/ha:			
	Date Applied	6/1/90	6/7/91
	Banvel	0.24	0.38
	2-4D Amine	0.24	0.38
	Lasso		0.38

The field operations, irrigation and drainage control schedule for the 1990 growing season is presented in Table 3, and for the 1991 growing season in Table 4.

Statistical Analysis

Regression analysis was performed after all observation points were calibrated in the field. The bubbler system pressure transducers have a linear response to change in pressure. Each pressure transducer was frequently calibrated to ensure it was operating within specifications. After all calibrations and regressions were performed, the correlation

Table 3. Fi
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Date
4/30/90 - 5/
5/8/90
5/8/90
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Table 3. Field operations, irrigation and drainage control schedule 1990

Date	Field Operation
4/30/90 - 5/1/90	Plowed using disk harrow
5/8/90	Planted Corn
5/8/90	Broadcasted Fertilizers, Preemergence
6/1/90	Sprayed Herbicides
6/3/90 & 6/18/90	Cultivated
7/1/90	SI put in controlled drain mode
7/3/90	SI irrigation started
7/8/90	SI irrigation suspended
7/18/90	SI put in drain mode
7/28/90	SI put in controlled drain mode
8/1/90	SI irrigation started
8/3/90	SI irrigation suspended
8/4/90	SI put in drain mode
8/8/90	SI put in controlled drain mode
8/26/90	SI put in drain mode
9/4/90	SI put in controlled drain mode
9/6/90	SI put in drain mode
9/12/90	SI put in controlled drain mode
9/12/90	SI irrigation started
9/14/90	SI irrigation suspended
9/14/90	SI put in drain mode for remainder of season and winter
11/8/90	SI and DO harvested
12/23/90	ND harvested

coefficient was determined and this was used as a guide as to whether observations were being made accurately.

The soil sample nutrient loadings were run through a standard two-sample t test for significant difference between each treatment. The formula given by Harnett (1970) takes the form:

$$t=\frac{\overline{x}-\mu}{S/n^{0.5}} \tag{6}$$

Table 4. Field op
schedule 1991

Date
5/12/91
5/21/91
5/27/91
6/7/91
7/10/91
7/11/91
7/18/91
7/21/91
7/24/91
7/28/91
8/7/91
8/10/91
8/17/91
8/19/91
9/3/91
10/8/91

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The leaf index

Table 4. Field operations, irrigation and drainage control schedule 1991

Date	Field Operation
5/12/91	Plowed using disk harrow
5/21/91	Planted Corn and Fertilized
5/27/91	SI put in controlled drain mode
6/7/91	Sprayed Herbicides, Preemergence
7/10/91	SI irrigation started
7/11/91	SI irrigation suspended
7/18/91	SI irrigation started
7/21/91	SI irrigation suspended
7/24/91	SI irrigation started
7/28/91	SI irrigation suspended
8/7/91	SI put in drain mode
8/10/91	SI put in controlled drain mode
8/17/91	SI put in drain mode
8/19/91	SI put in controlled drain mode
9/3/91	SI put in drain mode for season and winter
10/8/91	SI, DO and ND harvested

where:
- t = two-sample t-test value
- x = mean difference between sample sets
- μ = population mean difference of null hypothesis ($\mu_0 = \mu_1 - \mu_2 = 0$)
- S = standard deviation of sample difference
- n = number of sample differences tested

The null hypothesis states that between each of the 3 treatments, the difference between the sample averages is zero. The t-test value computed for all sample sets were tested at a significance level of 0.05. If the t value exceeds the critical value for the test run, the null hypothesis is rejected which means that there is high variation among samples analyzed between treatments. This test must be run before conclusions can be made when comparing results between treatments.

The leaf index and plant biomass results were tested for significant d

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significant difference between treatments using a randomized block design. The leaf index measurements for both growing seasons were plotted versus time and are shown in Appendix G. The test for significant difference between the leaf indexes from the three treatments were performed on the maximum observed leaf index for both growing seasons. The data table for a randomized block design and the format for the analysis of variance table follows the procedure described by Peterson (1985). A test of the significance of the differences among the treatment means is performed by F_T on the hypothesis $H_o: t_1 = t_2 = \cdots = t_p = 0$ against $H_a: t_1 \neq t_2 \neq \cdots \neq t_p \neq 0$. If the test shows significance (i.e. rejects H_o), then a further test of significance against which pairwise comparisons are judged was performed using Fisher's Protected LSD as described by Fisher (1966).

System Operation

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RESULTS AND DISCUSSION

System Operation Data

The pressure transducers used have a linear response in analog signal to changes in pressure caused by variations in depth. The regressions used in 1990 to obtain depths from the digitally converted signal, and the same for 1991 are presented in Appendix A. The lowest R^2 (correlation coefficient squared) was 0.817 for OWAHd5 (Observation Well, zone A, Head, well#5) in 1991. The differences in regression equations observed from 1990 compared to 1991 may have occurred due to the renovation of the system electronic components during the winter of 1990 and 1991. Changes also occurred due to the replacement of many of the microtubing lines in 1991. Water that got into some of the bubbler lines during both growing seasons affected the calibrations. The lines were routinely blown out using high air pressure during 1990 and 1991. There were periods when microtubing was damaged but still functional, and regression measurements were made for those periods. Slight changes in regression values from month to month in 1991 did occur, but not enough to warrant concern.

The regression equations Appendix A show inconsistencies in the slope values of different observation points that were read by the same pressure transducers. Much of this effect was attributed to damaged but useful air lines. Air lines that were mo

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Hydrology

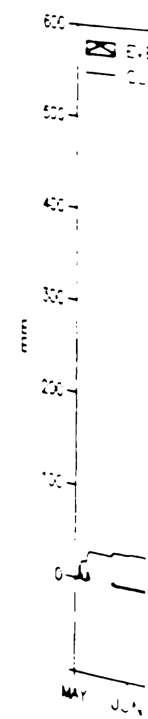

Figure 2. Sj

that were monitored by the same pressure transducer but showed inconsistent slope values were hooked to a different pressure transducer and calibrated. This test did not remove the inconsistencies in the slope values and the effect on the slope values was determined to be dependent on the air lines. The effect is more prevalent for the 1990 growing season than in 1991. New lines were installed for the flume and orifice monitoring wells in all treatments, but not for all the observation wells.

Hydrology

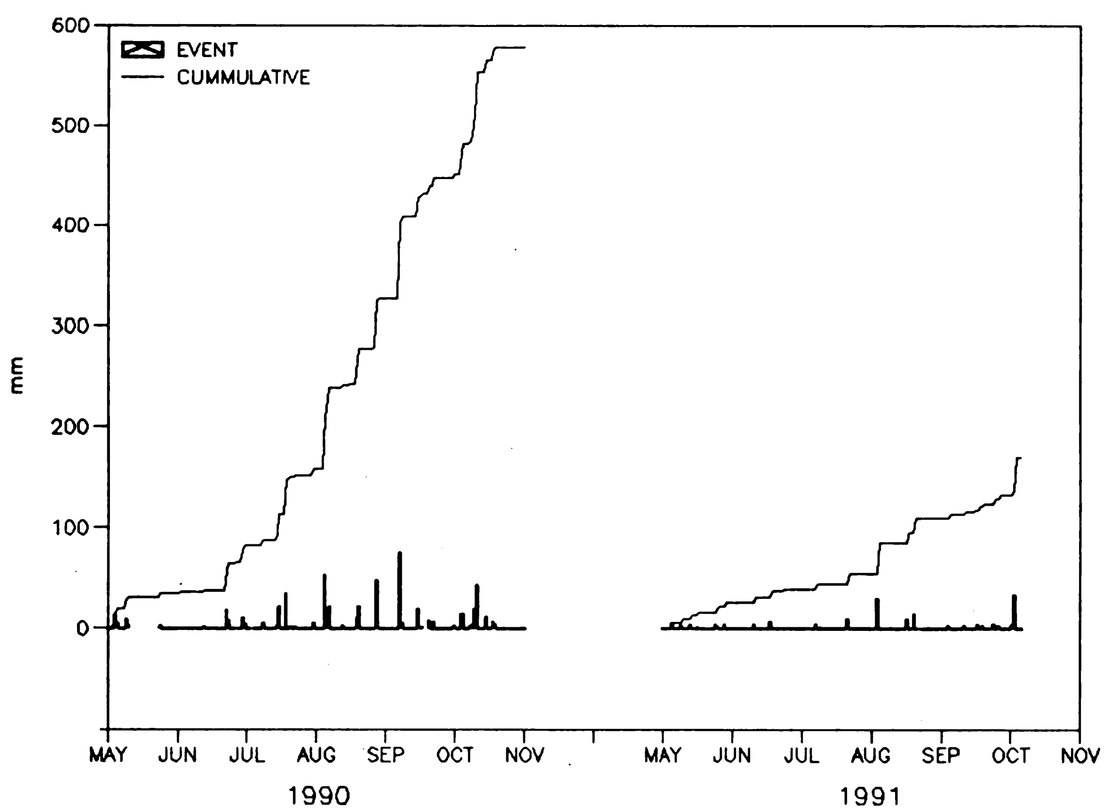

Figure 2. Site rainfall

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The accumulated rainfall and daily event rainfall from May 1, 1990 through October 31, 1990, and from May 1, 1991 through October 6, 1991 is plotted in Figure 2. The data collected by the LiCor weather station datalogger is presented in Appendix C. Accumulated rainfall for the 1990 growing season was 578 mm, and 170 mm for the 1991 growing season. The accumulated rainfall amounts of the 1990 and 1991 growing seasons were compared with the regional 30-yr average accumulated rainfall for both growing season periods as shown in Figure 3. During the 1990 growing season, accumulated rainfall exceeded the 30-yr average rainfall by 32%. During the 1991 growing season, accumulated rainfall was 52% below the 30-yr average.

Average daily water table depths for the 1990 and 1991 growing seasons are shown in Figures 5 and 6, respectively. The water table depths presented are the daily average of 6 observation wells in each treatment plot. The well depths, recorded every 20 minutes for each functional observation well, are shown in Appendix B. The elevation of the well top are reported in Appendix B as well. For the 1990 and 1991 growing seasons, the SI headstand was opened after substantial rainfalls and closed manually after the water table reached the desired depth of 0.4 to 0.6 m below ground surface. For both growing seasons, subirrigation was performed the months of July, August and September.

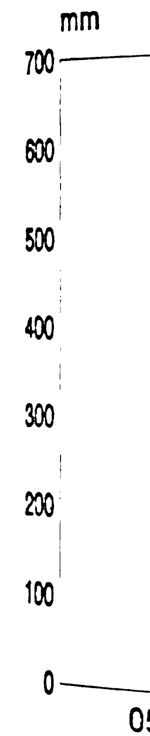
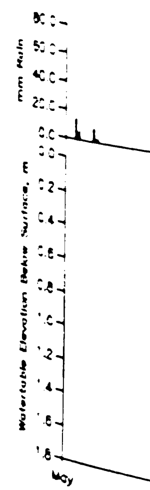


Figure 3. Co



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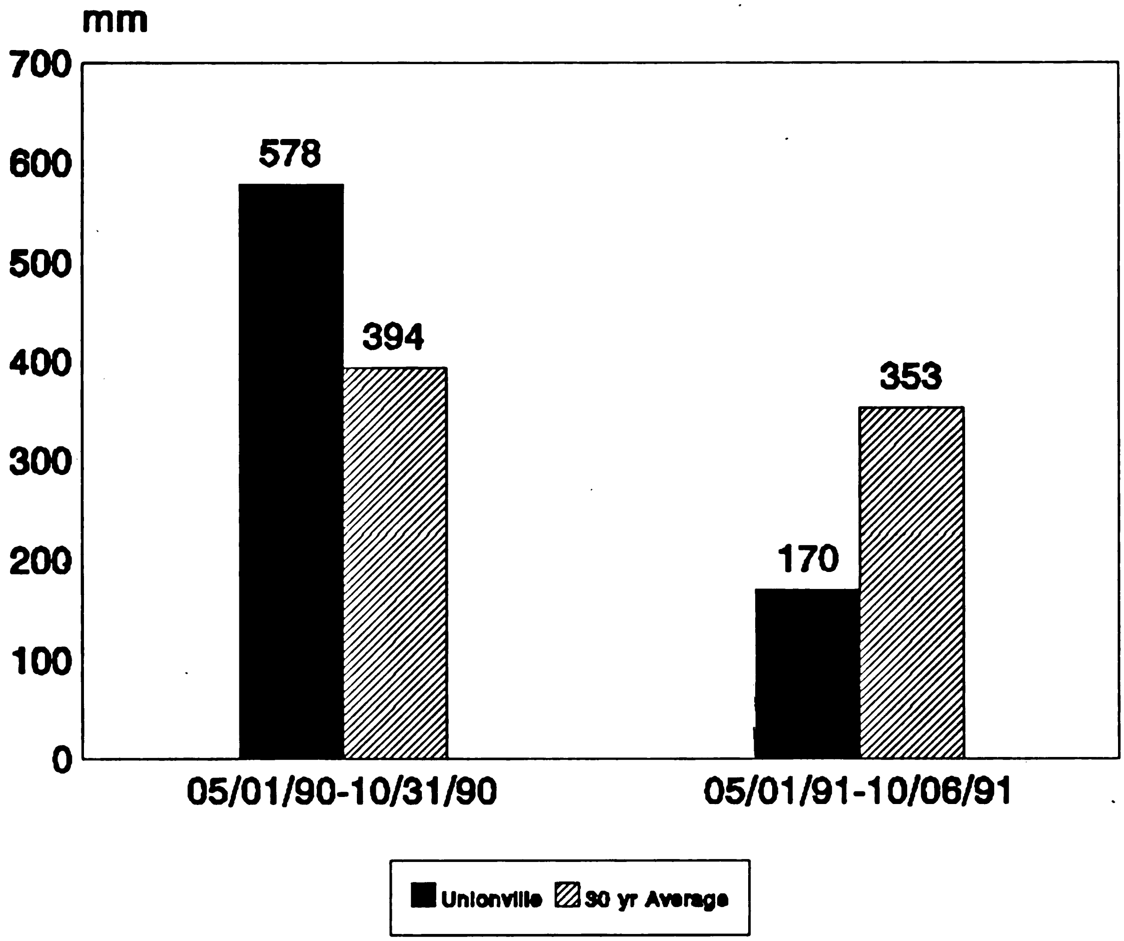


Figure 3. Comparison of site rainfall to seasonal average

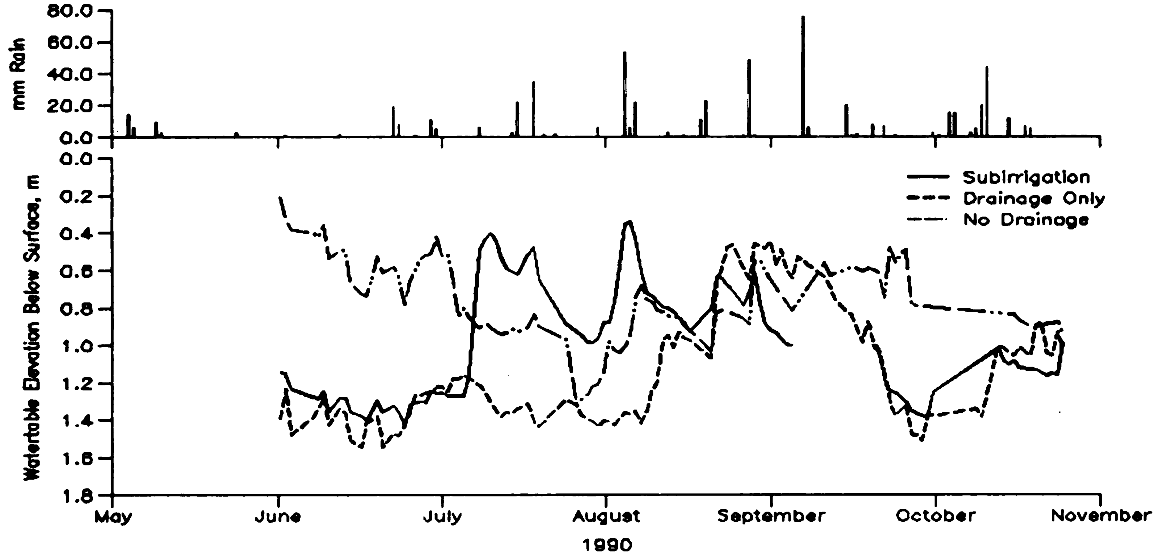
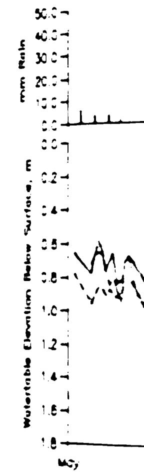


Figure 4. Watertable Depths 1990



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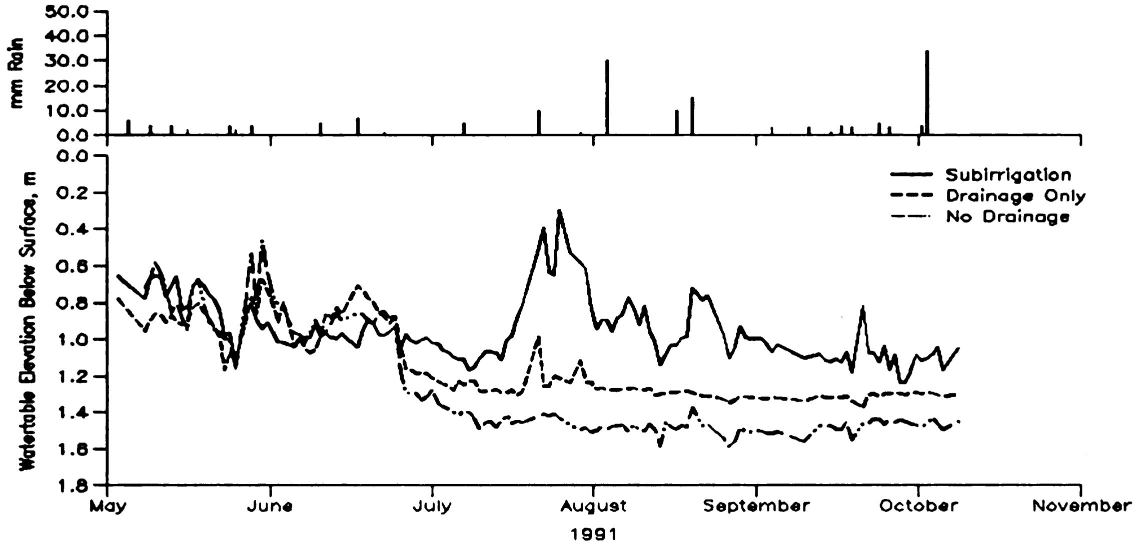

Figure 5. Watertable Depths 1991

During the 1990 growing season, frequent high events rainfall occurred at the end of July, August, September and October as shown in Figure 2. The headstand in the SI treatment was opened and closed to maintain the water table at or near 0.4 to 0.6 m during the period of drainage control and subirrigation. But due to the 1990 high event rains, maintaining the desired water table depth in the SI treatment proved to be difficult. The SI treatment was put into drainage mode for the remainder of the growing season on September 14, 1990 lowering the water table from 0.6 m below the ground surface to tile drain depth (0.8 m) so that harvesting could be performed. The low rainfall amounts that fell during the 1991 growing season allowed more constant control of the water table in the SI zone. The DO and ND treatments were very dry to the impermeable layer by the beginning of August through the end of the 1991 growing season.

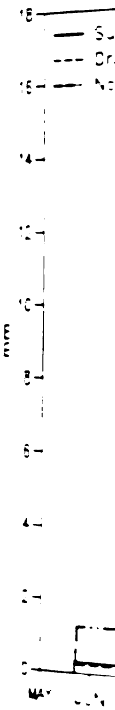

Figure 6. T

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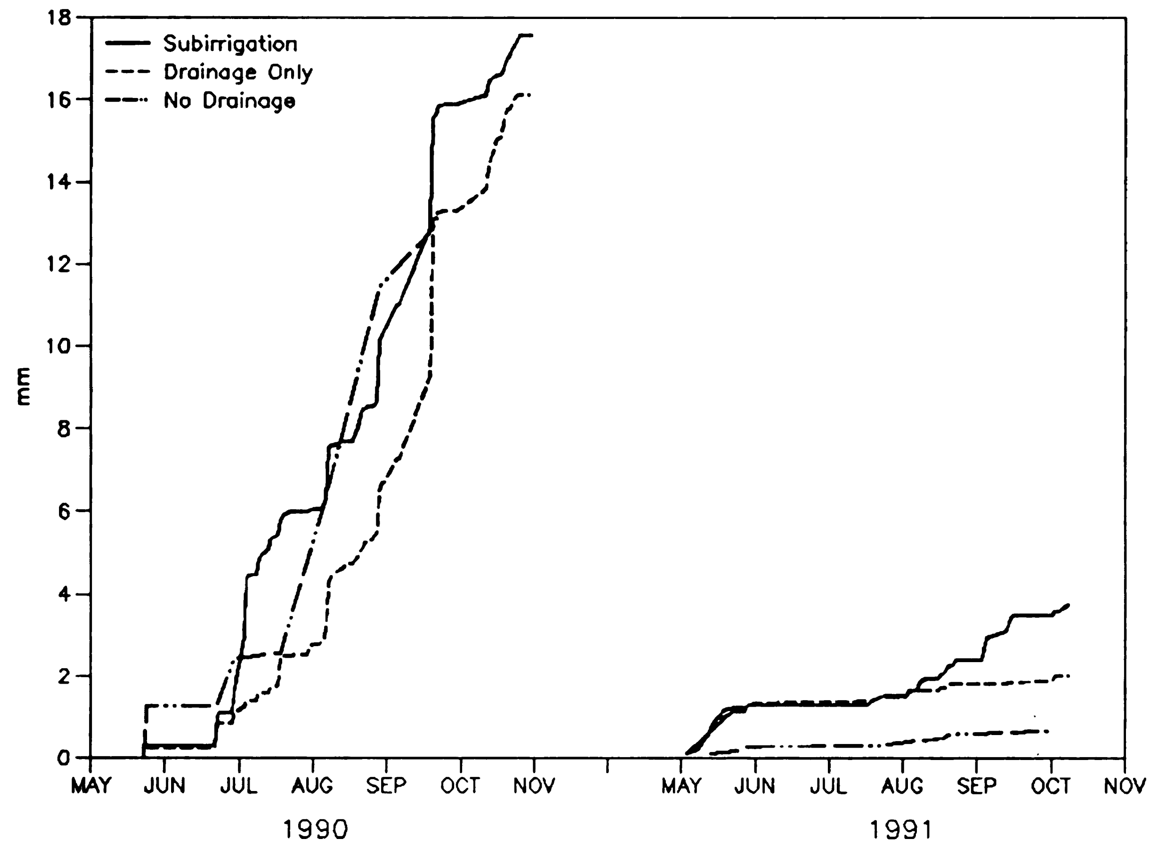

Figure 6. Total Drainage Volumes

The monthly accumulated tile and surface drainage discharge volumes from the SI and DO treatments, and the monthly accumulated surface drainage discharge volume from the ND treatment for the 1990 and 1991 growing seasons are presented in Table 5. The total accumulated tile and surface drainage outflow for both growing seasons are shown in Figure 6. The 1990 total drainage outflow from the SI treatment was 17.57 mm, 16.11 mm from the DO treatment, and 13.18 mm from the ND treatment. The 1991 total drainage discharge from the SI treatment was 3.74 mm, 2.00 mm from the DO treatment, and 0.66 mm from the ND treatment. The 1991 growing season had 71% less rain than during the 1990 growing season, which is why the drainage vo

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Table 5. Monthl

Month	Rai
1990	
May	35
June	47
July	76
August	169
Sept	124
Oct	127
Total=	578
1991	
May	
June	26
July	13
August	16
Sept	55
Oct	22
Total=	35
	170

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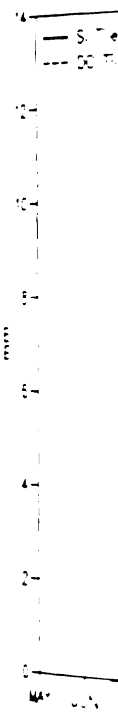
the drainage volumes for the 1991 growing season were substantially less. Campbell, et al. (1985) reported that subirrigation increased total drainage to edge of field compared to a water furrow system. Willard, et al. (1927), Schwab and Fouss (1967), Schwab, et al. (1980), Schwab et. al (1983), Jacobs and Gilliam (1985), Bottcher, et al. (1981), Skaggs, et al. (1982), and Evans and Skaggs (1989) reported increased total drainage to edge of field due from subsurface drainage compared to fields with no subsurface drainage.

Table 5. Monthly drainage discharge volumes

		SI		DO		ND
	Rain	Tile	Surface	Tile	Surface	Surface
Month	mm	mm		mm		mm
1990						
May	35	-	0.30	-	0.25	1.28
June	47	1.13	0.49	0.61	0.28	1.15
July	76	3.65	0.48	0.84	0.79	0.12
August	169	1.84	2.64	2.50	1.54	8.91
Sept	124	4.35	1.05	4.50	2.02	1.72
Oct	127	1.65	-	2.77	-	-
Total=	578	12.62	4.95	11.22	4.89	13.18
1991						
May	26	1.11	0.20	1.16	0.17	0.29
June	13	0.00	0.00	0.05	0.00	0.00
July	16	0.10	0.11	0.10	0.02	0.02
August	55	0.53	0.34	0.09	0.22	0.26
Sept	22	1.11	0.00	0.07	0.00	0.00
Oct	38	0.16	0.08	0.04	0.08	0.09
Total=	170	3.01	0.73	1.51	0.49	0.66

(Oct 1991 = Oct 1 - Oct 6, 1991)

The 1990 and 1991 growing season accumulated tile drainage from the SI and DO treatments are shown in Figure 7. The 1990 SI accumulated tile drainage outflow was 12.62 mm, and 11.22 mm from the DO treatment. The tile discharge from the SI treatment was 11% higher due to the irrigation of the SI



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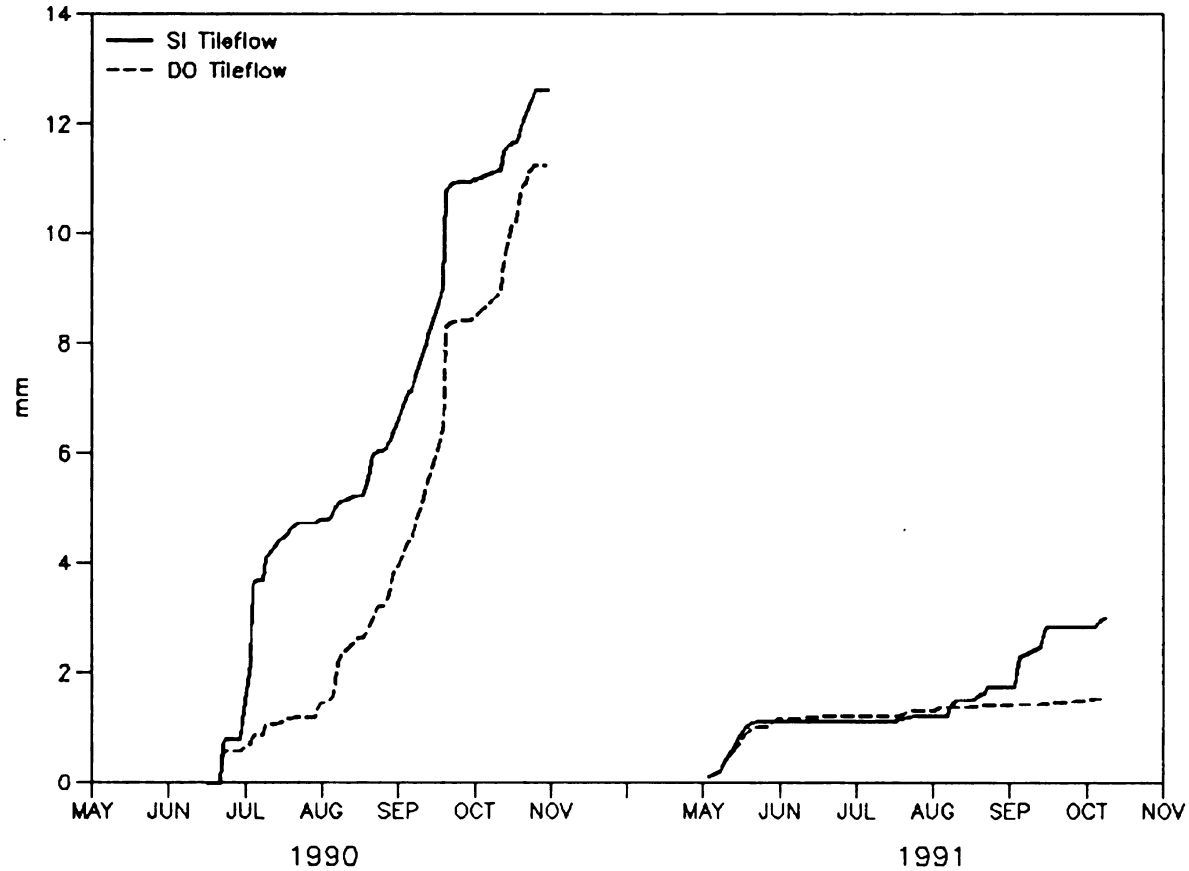

Figure 7. Tile Drainage Volumes

treatment. In addition, when irrigation of the SI treatment began on July 3, 1990, the control valve in the headstand was not properly set. It was not discovered and fixed until July 5, 1990. The SI tile drainage volume for July, 1990, was 3.65 mm, while the DO tile drainage volume was only 0.48 mm.

The 1991 growing season accumulated tile drainage from the SI and DO treatments are shown in Figure 8. The SI had 3.01 mm of accumulated tile discharge, and the DO treatment had 1.51 mm. As in 1990, the 50% increase in tile drainage from the SI treatment was due to irrigation.

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September of the 1990 growing season had the highest monthly accumulated tile drainage discharge for both the SI and DO treatments. The September tile drainage outflow from the SI treatment was 4.35 mm, and 4.50 mm from the DO treatment. Although the 169 mm of rain that fell during August, 1990, was the highest of the growing season, the SI treatment was still under controlled drainage, and the DO treatment still had storage capacity for water in the soil profile. At this point of the growing season, corn is still removing water from the soil. By September, the SI treatment was put in drainage mode for the remainder of the year, and the soil profiles of both the SI and DO treatments were near saturation from the continual rainfall thus resulting in the high tile drainage outflows.

The highest 1991 growing season monthly accumulated tile drainage volume occurred in May for both the SI and DO treatments. The tile drainage outflow measured resulted from the spring thaw. The SI treatment had 1.11 mm of tile drainage outflow in May, and in September, 1991, when the treatment was put in drain mode. The DO treatment had 1.16 mm of tile drainage outflow in May, after which drainage volumes did not exceed 0.10 mm for the remainder of the growing season.

Monthly accumulated surface drainage discharge volumes from all three treatments for both growing seasons are shown in

Table 5. The 199

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Table 5. The 1990 growing season accumulated surface drainage discharge from the SI treatment was 4.95 mm, 4.89 mm from the DO treatment, and 13.18 mm from the ND treatment. The SI and DO treatments had similar surface drainage volumes through out the 1990 growing season. The highest SI monthly surface drainage outflow of 2.64 mm occurred in August, 1990. The high water tables maintained by drainage control and the 169 mm of rainfall in August, 1990, contributed to high surface drainage outflow from the SI treatment.

The 1990 and 1991 growing season accumulated surface drainage outflow for all three treatments are shown in Figure 8. The SI treatment outflow was 1% higher than the DO treatment, and 62% lower than the ND treatment. Because there are no tile drains in the ND treatment, the soil profile became saturated from the high rain events, and excess water drained via the surface ditch. The rain intensity exceeded the infiltration capability of the soils in the SI and DO treatments resulting in high surface drainage outflow from mid-July through September, 1990. Willard, et al. (1927), Schwab and Fouss (1967), Schwab, et al. (1980), Schwab et. al (1983), Jacobs and Gilliam (1985), Bottcher, et al. (1981), Skaggs, et al. (1982), and Evans and Skaggs (1989) reported decreased accumulated surface drainage to edge of field due from subsurface drained fields compared to fields with no subsurface drainage. Campbell, et al. (1985) reported that subirrigation decreased surface drainage to edge of field compa

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The 1991 growing season surface drainage volumes for all three treatments shown in Figure 8 were substantially less than from 1990. The 1991 SI treatment surface drainage outflow was 29% greater than from the DO treatment, and 10% higher than from the ND treatment. The soil profile of the DO and ND treatments was near dry from July through the end of the 1991 growing season. Most rainfall water infiltrated and remained in the soil of all three treatments and was used by the corn instead of draining via the surface ditches. Gilliam and Skaggs (1986), and Deal, et al. (1986) reported that controlled drainage increased surface runoff compared to conventional subsurface drainage. Evans and Skaggs (1989) stress that the design and management of controlled drainage systems directly affect the amount of surface drainage to edge of field.

The DO treatment had the highest surface drainage outflow of 2.02 mm in September, 1990. The soil profile in the DO treatment could not store and sufficiently drain the subsurface water after the heavy rains of August, 1990, which resulted in increased surface drainage outflow in September, 1990. The ND treatment had substantially higher surface drainage volumes than the tile drained treatments for the 1990 growing season.

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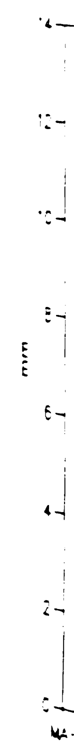

Figure

The 1991 growing season monthly surface drainage volumes from all three treatments were very low due to the low rainfall amounts. The 1991 growing season accumulated surface drainage discharge from the SI was 0.73 mm, 0.49 mm from the DO treatment, and 0.66 mm from the ND treatment. There was little difference in surface drainage volumes among the three treatments, except for the SI treatment in July and August, 1991. Raising the water table may have increased the surface outflow from the SI treatment during July and August. This was also noted in August of 1990.

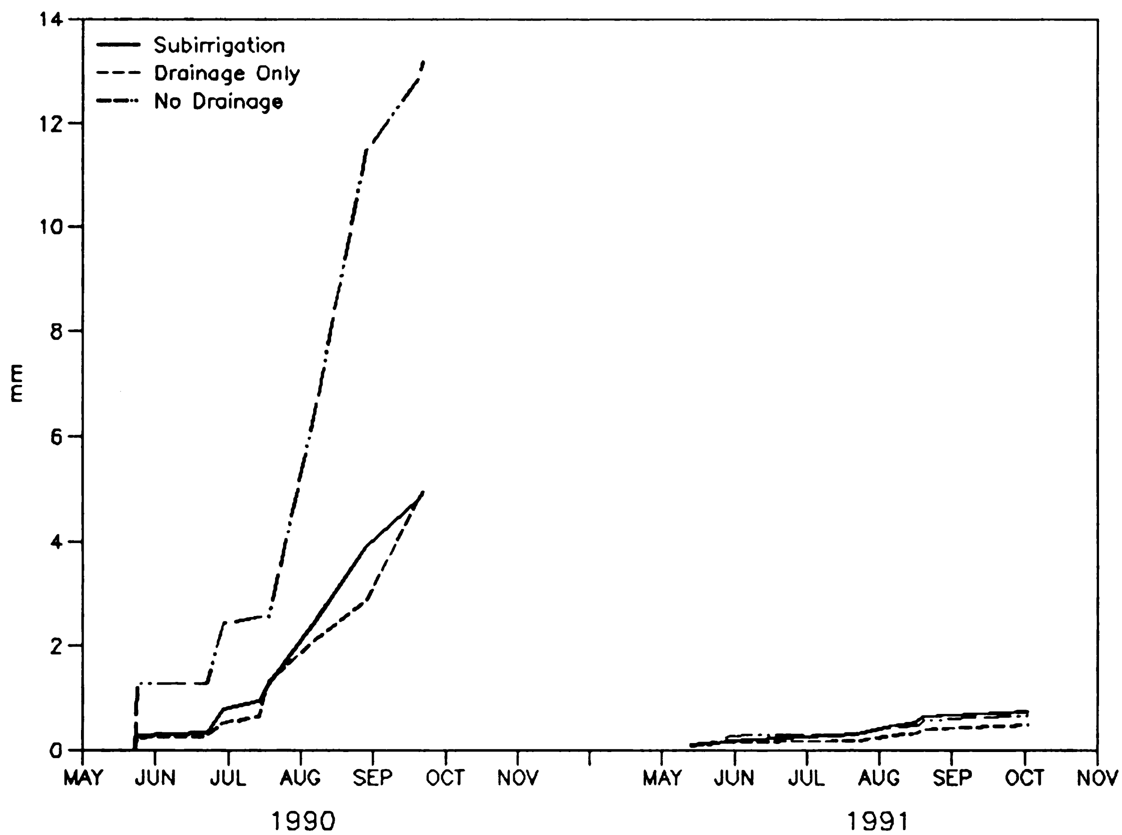

Figure 8. Surface Drainage Volumes

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Table 6. Rainfall nutrient loadings and concentrations

Date	NO_3-N		NH_4-N		PO_4-P		K	
Date	ppm	kg/ha	ppm	kg/ha	ppm	kg/ha	ppm	kg/ha
06/12/90	6.07	1.21			0.19	0.04	1.10	0.22
06/25/90	4.13	11.15			0.13	0.35	1.70	4.59
07/17/90	1.06	2.65			0.21	0.53	3.20	8.00
07/19/90	0.61	2.14			0.10	0.35	3.20	11.20
08/02/90	0.00	0.00			0.27	0.16	1.60	0.96
08/06/90	0.55	4.46			0.35	2.84	1.19	9.64
08/14/90	1.91	0.57			2.08	0.62	8.25	2.48
08/20/91	0.67	2.35			0.31	1.10	1.69	5.92
08/28/90	0.66	3.30			0.22	1.10	0.56	2.80
09/17/90	0.03	0.07			0.22	0.51	0.56	1.29
09/19/90	1.15	0.92			1.92	1.54	2.75	2.20
10/02/90	1.89	0.76			0.37	0.15	0.50	0.20
10/04/90	0.47	1.41			0.23	0.69	2.13	6.39
10/11/90	0.73	5.26			0.23	1.66	2.63	18.94
07/29/91	1.75	0.18	1.13	0.11	0.27	0.03	2.63	0.26
08/16/91	1.21	1.21	1.21	1.21	0.20	0.20	0.98	0.98
08/19/91	0.30	0.45	0.30	0.45	0.13	0.20	0.50	0.75

Nutrient concentrations and loadings of rain samples are presented in Table 6. Rain samples were not collected for all events for both the 1990 and 1991 growing seasons. The rain samples that were collected contained relatively high concentrations and loadings of nitrate nitrogen, orthophosphate phosphorus, potassium, and ammonia nitrogen. The extremely high concentrations and loadings of nitrate nitrogen found in the June, 1990, rain samples may be explained by the fact that, for those events, the collector was only 0.5 m above the ground and may have been contaminated by the surrounding soil.

There were no documented measurements of average regional rainfall nutrient concentrations and loadings found. There are many po

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are many possible sources of the nutrients found in the rain water samples. Nitrate and ammonia nitrogen may be in precipitation as a result of atmospheric fixation of nitrogen (Brady, 1984). The nitrogen source would include gaseous losses from the soils of the regional agricultural lands, and from animal manure from surrounding dairy and swine operations. Orthophosphate phosphorus sources above the soil surface are primarily from crop residues, animal manures, and chemical fertilizers. The orthophosphate phosphorus and potassium found in the rain samples would most likely be associated with particulate matter carried into the atmosphere by winds. This would primarily be soil dust or fine particles of dried animal manure. The surface soil at the site and in the area is easily eroded by wind when unprotected.

Nutrient concentrations of the irrigation water are presented in Table 7. Since the volume of irrigation water used was not monitored, loadings were not computed. The concentrations of orthophosphate phosphorus and potassium were relatively high in all irrigation samples tested. The source of the irrigation water is a nearby agricultural drainage channel containing backwater from the Saginaw Bay of Lake Huron. The drainage waters that enter the channel probably carry substantial concentrations of nutrients.

Average monthly nitrate nitrogen, orthophosphate phosphorus, and potassium concentrations in samples collected from the tile drain outflow of the SI treatment are presented in Table

Table 7. I

Date
08/02/90
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07/18/91
07/24/91

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Table 8.

Month	
1989	
November	
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April	
May	
June	
July	1
August	2
Sept	1
October	1
1991	
May	
June	2
July	1
August	1
Sept	1
October	

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Table 7. Irrigation water nutrients

	ppm			
Date	NO_3-N	NH_4-N	PO_4-P	K
08/02/90	0.00		0.10	2.60
09/12/90	3.50		0.10	2.80
07/18/91	0.00	0.18	0.11	2.10
07/24/91	0.30	0.09	0.12	2.10

8. The concentrations of the same nutrients in samples collected from the tile drain outflow of the DO treatment are presented in Table 9. All 1991 ammonia nitrogen concentrations and loadings found in tile and surface drainage samples are presented following the results and discussion of drainage water concentrations and loadings of nitrate nitrogen, orthophosphate phosphorus, and potassium.

Table 8. SI tile drainage nutrient concentrations

		NO_3-N, ppm			PO_4-P, ppm			K, ppm		
Month	n	MEAN	HIGH	LOW	MEAN	HIGH	LOW	MEAN	HIGH	LOW
1989										
November	4	14.5	21.1	9.3	0.06	0.07	0.05	8.0	15.0	5.0
1990										
April	2	8.5	8.7	8.2	0.09	0.09	0.08	14.7	14.7	14.7
May	6	11.3	15.5	9.4	0.08	0.10	0.05	14.1	22.6	8.4
June	5	13.4	17.0	10.4	0.03	0.07	0.00	8.4	10.0	4.4
July	15	1.5	9.3	0.0	0.09	0.13	0.07	3.7	8.9	2.1
August	21	7.5	17.2	0.8	0.26	0.36	0.01	12.8	31.6	3.2
Sept	17	19.2	31.3	6.4	0.23	0.27	0.18	16.2	39.5	2.3
October	11	32.6	38.4	17.9	0.21	0.23	0.16	18.3	45.7	13.3
1991										
May	7	17.6	31.6	10.0	0.11	0.12	0.08	10.4	15.8	4.8
June	21	19.3	23.5	7.8	0.11	0.12	0.09	25.6	38.6	1.1
July	16	7.4	25.9	0.0	0.11	0.13	0.10	10.6	27.3	2.1
August	11	0.7	1.4	0.1	0.11	0.14	0.10	3.4	4.8	2.1
Sept	11	0.5	0.9	0.1	0.15	0.16	0.12	3.8	4.8	2.6
October	1	1.0			0.15			1.1		

The concentrations of nitrate-nitrogen in tile drainage samples were higher from the DO treatment than from the SI samples during both the 1990 and 1991 growing seasons. The

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Table 9. DO tile drainage nutrient concentrations

		NO_3-N, ppm			PO_4-P, ppm			K, ppm		
Month	n	MEAN	HIGH	LOW	MEAN	HIGH	LOW	MEAN	HIGH	LOW
1989										
November	4	17.6	23.0	12.7	0.06	0.06	0.05	8.8	18.0	5.0
1990										
April	2	24.3	24.9	23.6	0.09	0.10	0.07	6.1	6.3	5.8
May	6	18.0	22.0	15.9	0.09	0.10	0.07	4.5	5.3	3.7
June	5	17.2	22.2	15.9	0.05	0.19	0.00	5.8	8.9	4.7
July	14	27.2	64.8	7.9	0.10	0.17	0.00	4.7	8.4	2.6
August	18	42.7	60.5	0.1	0.30	1.02	0.00	6.1	7.1	4.1
Sept	18	52.8	77.5	21.4	0.22	0.25	0.07	7.2	8.9	3.9
October	9	65.1	81.3	52.4	0.22	0.25	0.20	6.4	7.4	6.2
1991										
May	13	17.8	46.7	4.3	0.10	0.13	0.00	3.5	5.8	2.1
June	21	23.5	34.3	10.5	0.11	0.12	0.09	4.5	6.7	2.3
July	13	19.6	29.8	0.0	0.11	0.13	0.09	4.7	6.1	2.6
August	9	11.5	15.2	5.7	0.20	0.72	0.10	4.5	5.8	3.2
Sept	4	6.9	6.9	4.5	0.16	0.18	0.15	5.9	6.3	5.8
October	1	0.7			0.14			1.6		

only exception occurred in the one sample collected from each treatment within the first 6 days of October, 1991.

Grab samples were taken from the headstand of the SI and DO treatments in November, 1989, and the average nitrate nitrogen concentration of the SI treatment tile water samples was 14.5 ppm, and 17.6 ppm in the DO treatment samples. The concentrations found in grab samples taken from the SI headstand decreased to 8.5 ppm in April, 1990. When samples were taken based on flow beginning in June, 1990, the average concentration in SI tile water samples increased slightly to 13.4 ppm nitrate nitrogen, but fell to 1.5 ppm in July, 1990. With the heavy rains of late July through October of 1990, the average concentrations in the tile drainage outflow increased to 32.6 ppm nitrate nitrogen in October due to the higher subsurface drainage flow.

The average concentrations of nitrate nitrogen found in grab samples taken from the DO treatment headstand in April, 1990, were 24.3 ppm. The average nitrate nitrogen concentrations decreased in May and June, 1990, and increased from July through October, 1990, due to the heavy rains which leached more nitrate nitrogen with the increased subsurface drainage outflow. In October, 1990, the highest DO treatment average nitrate nitrogen concentration of 65.1 ppm was observed.

Through out the 1991 growing season, all samples taken from the SI and DO treatment headstands were flow based. The SI average monthly nitrate nitrogen concentration in May, 1991, was 17.6 ppm, and 17.8 ppm from the DO treatment tile drainage outflow. During June, 1991, the bubbler system was miscalculating flow rates and activating the tile drain samplers when little to no tile flow occurred. These samples from both treatments observed an increase in nitrate nitrogen concentrations. The SI treatment tile drainage nitrate nitrogen concentrations decreased to 7.4 ppm in July, 1991, and decreased to less than or equal to 1 ppm nitrate nitrogen from August through October, 1991.

The DO treatment observed a gradual decrease in nitrate nitrogen concentrations in tile drainage outflow from July through October, 1991. The July and August, 1991, DO average tile nitrate nitrogen concentrations remained above the 10 ppm drinking water standard, but fell below 1 ppm in one sample taken in October, 1991.

Because of the high solubility of nitrate nitrogen, holding the water in the SI treatment by controlling the subsurface drainage reduced the nitrate nitrogen concentrations leached to the tile drains compared to the DO treatment. The average monthly orthophosphate phosphorus concentrations from the SI and DO tile drainage outflow showed little difference for most months as shown in Tables 10 and 11.

Orthophosphate phosphorus appeared in higher quantities in the tile drainage water during periods of higher tile outflow, indicating the propensity of orthophosphate phosphorus to move through the soil and be discharged from the drainage system during periods of excess soil water. The concentrations of orthophosphate phosphorus found in the tile drainage outflow from both treatments remained lower than concentrations found in the rain samples through most of both growing seasons.

Phosphorus is generally low in the subsoils through which subsurface drainage water must pass, and thus are generally low in tile drain water (Campbell et al., 1985). Phosphorus is generally referred to as a soil bound nutrient, and usually is lost from surface drainage. As a soil bound nutrient, the source of orthophosphate phosphorus in the rain samples was probably in soil particulate matter and to a less degree animal manure particles carried by atmospheric winds and brought down by precipitation. These orthophosphate phosphorus concentrations in the precipitation were higher than from the subsurface drainage waters.

Both treatments observed tile drainage outflow concentrations of 0.09 ppm orthophosphate phosphorus in April, 1990. The SI treatment decreased to 0.03 ppm orthophosphate phosphorus in June, 1990, and increased with the increased tile drainage outflow through July and August to 0.26 ppm, the highest average concentration found from the SI treatment during both growing seasons.

The DO treatment decreased to 0.05 ppm orthophosphate phosphorus in June, 1990, and increased with the increased tile drainage outflow through July and August to 0.30 ppm, which was the highest observed in the DO treatment tile drainage outflow. The concentrations in the DO treatment tile drainage outflow remained above 0.20 ppm through October, 1990. In August, 1990, a DO treatment tile water sample had an orthophosphate phosphorus concentration of 1.02 ppm, the only tile drainage sample found to exceed the 1.0 ppm recommended maximum concentration level.

The orthophosphate phosphorus concentrations in tile drainage from the SI an DO treatments remained around 0.11 ppm from May through July, 1991. The SI treatment observed a small increase to 0.15 ppm orthophosphate phosphorus in September, 1991, which was when the SI treatment was put in drainage mode for the remainder of the season. This subsurface drainage water may have leached out higher concentrations of orthophosphate phosphorus from the soil. The DO treatment average monthly orthophosphate phosphorus concentrations in tile drainage increased to 0.20 ppm in August, 1991. Minimal tile drainage outflow occurred from the DO treatment June through October, 1991. The increase in orthophosphate phosphorus concentrations in tile drainage outflow during August, 1991, followed the same trend observed with both the SI and DO treatments in 1990. This may result from the corn using less orthophosphate phosphorus, thus rendering residual phosphorus susceptible to leaching.

The 1990 growing season average monthly potassium concentrations were considerably higher in tile drain outflow from the SI treatment than from the DO treatment every month except July, 1990. Potassium concentrations in the SI treatment tile drainage outflow were high in the spring, decreased substantially by July, 1990, and then increased from August through October, 1990. In October, 1990, the highest average potassium concentration of 18.3 ppm was observed in the SI tile drainage outflow. The DO treatment had no trend in the tile drainage outflow potassium concentrations for the 1990 growing season.

Potassium behaves similarly to phosphorus with regard to being tied up by microbial activity in the soil. But potassium is readily lost by leaching, even to the extent that the amount leached may equal that used by the crop (Lyon et al., 1952). Potassium will move through the soil in large quantities under saturated conditions. It is possible that since the SI treatment soil profile was saturated up to 0.6 m below the soil surface and moist almost to the surface, and the DO treatment had a water table kept at or below tile drain depth, more potassium would be lost through the SI treatment than from the DO treatment.

The 1991 growing season SI treatment observed high average monthly potassium concentrations in the tile drainage outflow from May through July, but decreased as tile drainage from the SI treatment increased August through October, indicating that the corn may have used up most of the potassium, leaving little residuals susceptible to leaching when the SI treatment was put in drain mode.

The monthly average nitrate nitrogen, orthophosphate phosphorus, and potassium concentrations in surface drainage outflow from the SI, DO and ND treatments are presented in Tables 10, 11, and 12, respectively.

The 1990 growing season highest monthly average nitrate nitrogen concentration from the SI treatment surface drainage was 14.9 ppm in July. The DO treatment observed its highest

Table 10. SI surface drainage nutrient concentrations

Month	n	NO$_3$-N, ppm MEAN	HIGH	LOW	PO$_4$-P, ppm MEAN	HIGH	LOW	K, ppm MEAN	HIGH	LOW
1990										
May	0	-	-	-	-	-	-	-	-	-
June	2	14.6	20.5	8.7	0.01	0.02	0.00	13.1	19.5	6.7
July	5	14.9	20.9	4.5	0.13	0.16	0.09	9.9	21.4	3.2
August	3	4.9	8.9	1.8	0.31	0.35	0.22	5.4	5.9	4.4
Sept	2	5.0	7.0	2.9	0.24	0.24	0.23	6.9	9.4	4.4
October	1	1.5	-	-	0.25	-	-	12.9	-	-
1991										
May	4	8.3	21.1	0.2	0.19	0.26	0.10	6.8	16.3	0.5
June	0	-	-	-	-	-	-	-	-	-
July	2	1.0	1.0	0.9	0.11	0.11	0.10	1.6	1.6	1.6
August	4	0.9	1.6	0.9	0.11	0.12	0.11	6.3	22.6	0.5
Sept	0	-	-	-	-	-	-	-	-	-
October	2	1.5	2.0	1.5	0.11	0.15	0.07	0.5	0.5	0.5

Table 11. DO surface drainage nutrient concentrations

Month	n	NO$_3$-N, ppm MEAN	HIGH	LOW	PO$_4$-P, ppm MEAN	HIGH	LOW	K, ppm MEAN	HIGH	LOW
1990										
May	1	2.1	-	-	0.04	-	-	2.6	-	-
June	0	-	-	-	-	-	-	-	-	-
July	3	4.2	5.8	3.0	0.12	0.16	0.09	4.9	5.0	3.7
August	4	1.1	1.6	0.7	0.31	0.35	0.21	2.9	3.5	2.4
Sept	3	14.9	37.0	1.5	0.24	0.24	0.23	8.3	12.6	6.1
October	5	1.1	1.3	0.7	0.23	0.26	0.21	9.5	12.5	5.8
1991										
May	6	9.5	30.2	0.5	0.15	0.19	0.12	7.6	18.4	1.6
June	0	-	-	-	-	-	-	-	-	-
July	2	1.0	1.0	0.9	0.12	0.13	0.10	10.5	12.1	8.9
August	4	0.9	1.6	0.4	0.11	0.11	0.10	0.9	1.1	0.5
Sept	0	-	-	-	-	-	-	-	-	-
October	2	1.1	1.1	1.1	0.15	0.16	0.14	1.0	1.6	0.5

monthly average surface drainage nitrate nitrogen concentration of 14.9 ppm in September, which was when the ND treatment high of 16.0 ppm occurred.

The surface drainage outflow nitrate nitrogen concentrations were much lower from all three treatments for the 1991 growing season. All three treatments observed highest 1991 average monthly surface drainage nitrate nitrogen concentrations in

Table 12. ND surface drainage nutrient concentrations

		NO_3-N, ppm			PO_4-P, ppm			K, ppm		
Month	n	MEAN	HIGH	LOW	MEAN	HIGH	LOW	MEAN	HIGH	LOW
1990										
May	0	-	-	-	-	-	-	-	-	-
June	0	-	-	-	-	-	-	-	-	-
July	6	3.6	8.6	0.5	0.11	0.19	0.09	5.2	9.4	2.1
Aug	6	4.9	17.8	0.4	0.29	0.35	0.20	3.6	5.0	2.4
Sept	5	16.0	30.9	1.4	0.24	0.24	0.23	11.8	19.5	8.3
Oct	2	2.2	3.0	1.4	0.21	0.22	0.20	24.0	29.5	18.5
1991										
May	6	4.6	31.3	1.1	0.09	0.14	0.00	8.4	21.5	1.6
June	0	-	-	-	-	-	-	-	-	-
July	2	0.6	0.6	0.6	0.18	0.18	0.18	1.1	1.1	1.1
Aug	4	0.6	1.3	0.0	0.12	0.13	0.11	2.8	4.8	1.1
Sept	0	-	-	-	-	-	-	-	-	-
Oct	2	0.8	1.0	0.6	0.16	0.16	0.15	1.6	2.1	1.1

May. The SI treatment had 8.3 ppm, the DO treatment had 9.5 ppm, and the ND treatment had 4.6 ppm nitrate nitrogen found in the surface drainage outflow.

There was little difference in monthly average orthophosphate phosphorus concentrations from the surface drainage outflow of the three treatments. The 1990 concentrations in surface drainage outflow increased in August, September and October due to the heavy rains that occurred over that period. The concentrations remained relatively the same through out the 1991 growing season.

The highest 1990 monthly average potassium concentration in the SI treatment surface drainage outflow was 13.1 ppm which was measured in June. The highest 1990 monthly average potassium concentration in the DO treatment surface drainage was 9.5 ppm, and 24.0 ppm in the ND treatment surface drainage, which were both measured in October. Both the DO and ND treatments observed highest surface drainage potassium concentrations in September and October, 1990. Although the heaviest rains occurred in August, 1990, the heaviest potassium concentrations in surface drainage outflow from the DO and ND treatments did not occur until the soil profile became saturated with the continued high rainfall from September through October, 1990.

The SI treatment rendered more potassium to leach in tile drainage outflow than from surface drainage outflow due to the very wet soil conditions that were maintained during subirrigation. The potassium concentrations removed in the DO surface drainage were not much different than removed from the DO tile drainage. Having open subsurface drainage did not allow the soil profile in the DO treatment to become saturated. This prevented less leaching of potassium to tile drainage outflow from the DO treatment than from the SI treatment.

The 1991 growing season monthly average surface drainage potassium concentrations were generally lower from all three treatments. The 1991 highest average monthly potassium concentration from the SI treatment surface drainage was 6.8 ppm measured in May. The DO treatment highest concentration of 10.5 ppm occurred in July, and the ND treatment highest concentration of 8.4 ppm occurred in May.

Table 13. SI Treatment Monthly Drainage Nutrient Loadings

	Tile Drainage			Surface Drainage		
	NO_3-N	PO_4-P	K	NO_3-N	PO_4-P	K
Month		kg/ha			kg/ha	
1990						
May	-	-	-	-	-	-
June	0.07	0.003	0.19	0.016	0.0000	0.009
July	1.32	0.008	0.69	0.017	0.0003	0.012
August	0.07	0.003	0.23	0.443	0.0242	0.432
September	2.61	0.030	2.30	0.013	0.0010	0.047
October	1.17	0.010	0.81	-	-	-
Total=	5.24	0.054	4.22	0.489	0.0255	0.500
1991						
May	0.192	0.002	0.135	0.010	0.000	0.008
June	0.000	0.000	0.000	0.000	0.000	0.000
July	0.000	0.000	0.002	0.001	0.000	0.002
August	0.002	0.000	0.011	0.003	0.001	0.016
September	0.012	0.004	0.086	0.000	0.000	0.000
October	0.001	0.000	0.001	0.001	0.000	0.000
Total=	0.207	0.006	0.235	0.015	0.001	0.026

(Oct 1991 = Oct 1 - Oct 6, 1991)

The 1990 and 1991 growing season monthly nutrient loadings in surface and tile discharge from the SI, DO and ND treatments are presented in Tables 13, 14 and 15, respectively. The total cumulative nitrate nitrogen loadings measured in both surface and tile drainage are shown in Figure 9.

The 1990 accumulated nitrate nitrogen loadings from the SI treatment was 5.73 kg/ha, 13.90 kg/ha from the DO treatment, and 3.42 kg/ha from the ND treatment. The SI treatment

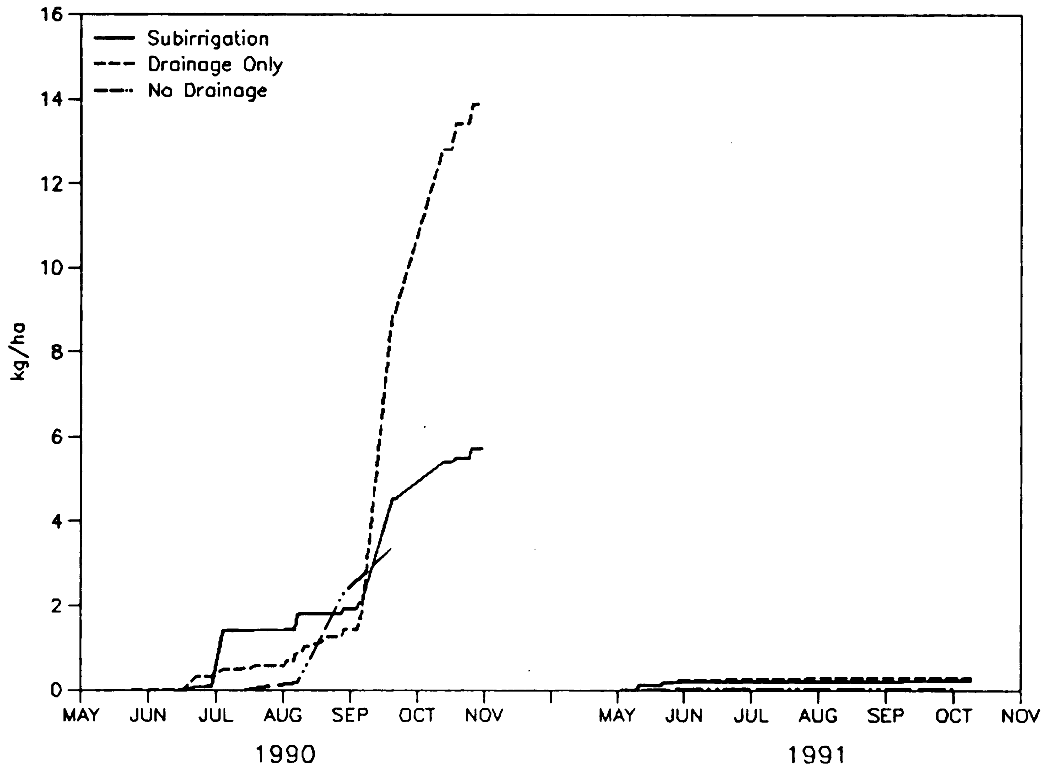

Figure 9. Total Drainage Nitrate-N Loadings

through controlling the water table reduced the nitrate nitrogen loadings loss through overall drainage by 59% compared to the DO treatment, and increased loadings by 40% compared to the ND treatment.

The 1991 growing season total cumulative nitrate nitrogen loadings from both surface drainage and tile drainage for the SI treatment was 0.23 kg/ha, 0.30 kg/ha for the DO treatment, and 0.03 kg/ha from the ND treatment The SI treatment reduced the nitrate nitrogen loadings loss through overall drainage by 30% compared to the DO treatment, and increased loadings 87% compared to the ND treatment.

Table 14. DO Treatment Monthly Drainage Nutrient Loadings

	Tile Drainage			Surface Drainage		
	NO_3-N	PO_4-P	K	NO_3-N	PO_4-P	K
Month		kg/ha			kg/ha	
1990						
May	-	-	-	0.003	0.0000	0.002
June	0.32	0.002	0.27	0.004	0.0002	0.009
July	0.19	0.000	0.06	0.053	0.0012	0.049
August	0.79	0.007	0.13	0.070	0.0193	0.209
September	7.43	0.030	1.00	0.053	0.0131	0.383
October	4.99	0.018	0.49	-	-	-
Total=	13.72	0.057	1.96	0.183	0.0338	0.652
1991						
May	0.211	0.002	0.032	0.010	0.009	0.132
June	0.029	0.000	0.005	0.000	0.000	0.000
July	0.025	0.000	0.007	0.000	0.000	0.000
August	0.014	0.000	0.005	0.002	0.000	0.002
September	0.006	0.000	0.006	0.000	0.000	0.000
October	0.000	0.000	0.000	0.001	0.000	0.001
Total=	0.285	0.002	0.054	0.013	0.009	0.135

(Oct 1991 = Oct 1 - Oct 6, 1991)

Schwab, et al. (1980) reported that subsurface drainage increased nitrate nitrogen by 35% compared to a surface drainage only treatment. Jacobs and Gilliam (1985) reported that subsurface drainage increased nitrate nitrogen loadings by 82% compared to a surface drainage system. Campbell, et al., (1985) reported a 39% decrease in total nitrate nitrogen loadings from a subirrigation system compared to a water furrow system. Gilliam and Skaggs (1986) reported a 47% reduction in total nitrate nitrogen loadings from controlled drainage compared to conventional subsurface drainage. Deal, et al. (1986) predicted a 33% reduction in nitrate nitrogen loadings from controlled drainage compared to conventional drainage using DRAINMOD.

Skaggs and Gilliam (1981) predicted a 38% reduction in nitrate nitrogen loadings from a drainage treatment controlled during

Table 15. No Drainage (ND) Treatment Monthly Drainage Discharge Nutrient Loadings

Month	NO_3-N	ND PO_4-P kg/ha	K
1990			
May	-	-	-
June	0.00	0.000	0.00
July	0.01	0.000	0.02
August	2.29	0.116	1.24
September	1.12	0.014	0.66
October	-	-	-
Total=	3.42	0.131	1.92
1991			
May	0.0313	0.000	0.026
June	0.0000	0.000	0.000
July	0.0002	0.000	0.000
August	0.0123	0.001	0.008
September	0.0000	0.000	0.000
October	0.0007	0.000	0.002
Total=	0.0334	0.001	0.036

(Oct 1991 = Oct 1 - Oct 6, 1991)

the winter compared to a conventional drainage treatment with both having good surface drainage provided. When controlled drainage was practiced all year, the reduction was 64%. For fields with poor surface drainage, the loadings from the drainage treatment controlled during the winter were reduced by 18%, and were the same when drainage was controlled all year.

The months with highest tile outflow volumes from both the SI and DO treatments also contained the highest nitrate nitrogen loadings. The highest accumulated monthly nitrate nitrogen loading in SI tile drainage outflow of 2.61 kg/ha occurred in September, 1990, which is when the SI treatment was put into drainage mode for the season. The highest DO tile drainage nitrate nitrogen loading of 7.43 kg/ha was measured in

September, 1990. The increased loadings were attributed to the increased tile drainage outflow caused by the high rainfall events in August through October. The 1991 tile drainage nitrate nitrogen loadings observed the same trend as in 1990 for both the SI and DO treatments, but the values were much lower due to much lower tile drainage outflow.

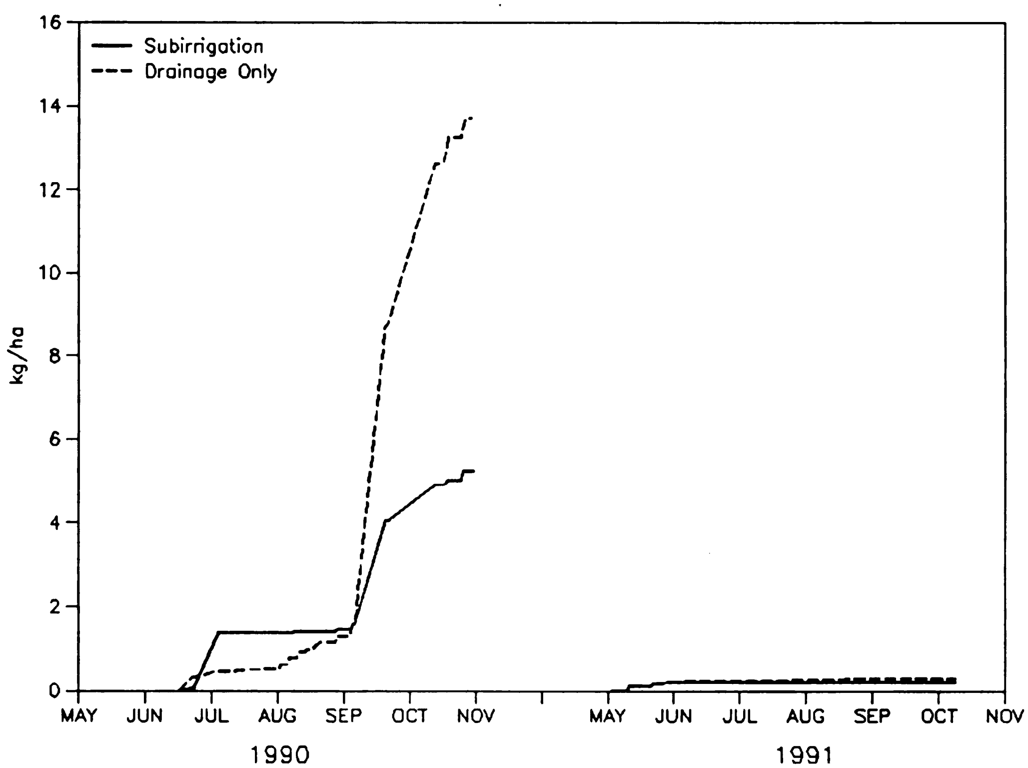

Figure 10. Tile Drainage Nitrate-N Loadings

The 1990 and 1991 growing season cumulative nitrate nitrogen loadings in tile drainage waters from the SI, DO and ND treatments are shown in Figure 10. The accumulated nitrate nitrogen loading in the SI tile drainage water was 5.24 kg/ha, and 13.72 kg/ha from the DO tile drainage outflow. The SI ti

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tile drainage nitrate nitrogen loading from June through October was 62% less from the SI treatment than from the DO treatment. The 1991 growing season accumulated SI tile drainage nitrate nitrogen loading was 0.21 kg/ha, and 0.29 kg/ha from the DO tile drainage outflow. The SI treatment reduced nitrate loadings in tile drainage outflow by 25%.

Gilliam, et al. (1979) reported a 88% reduction of nitrate nitrogen loadings in subsurface drain flow from controlled drained fields with moderately well drained soils compared to conventional subsurface drained fields of similar soil type. The reduction was approximately 50% for poorly drained soils.

Deal, et al. (1986) predicted a 42% reduction in subsurface drainage nitrate nitrogen loadings of a controlled drainage treatment compared to a treatment under conventional subsurface drainage. Evans and Skaggs (1989) reported a 87% reduction in subsurface drain nitrate nitrogen loadings from a controlled drained treatment compared to a treatment under conventional drainage.

The highest 1990 growing season monthly nitrate nitrogen loadings in surface drainage outflow occurred during the months with the highest monthly surface drainage outflow for all three treatments. The SI treatment highest surface drainage outflow occurred in August, and contained 0.44 kg/ha nitrate nitrogen. The DO treatment highest monthly surface drainage occurred in September, and contained 0.07 kg/ha nitrate nitrogen. The ND treatment also had the highest drainage outflow in September, and contained 3.42 kg/ha nitrate nitrogen. For the 1991 growing season, surface drainage outflow nitrate loadings were substantially less. The highest monthly loadings from all three treatments occurred in May, 1991, and did not exceed 0.03 kg/ha.

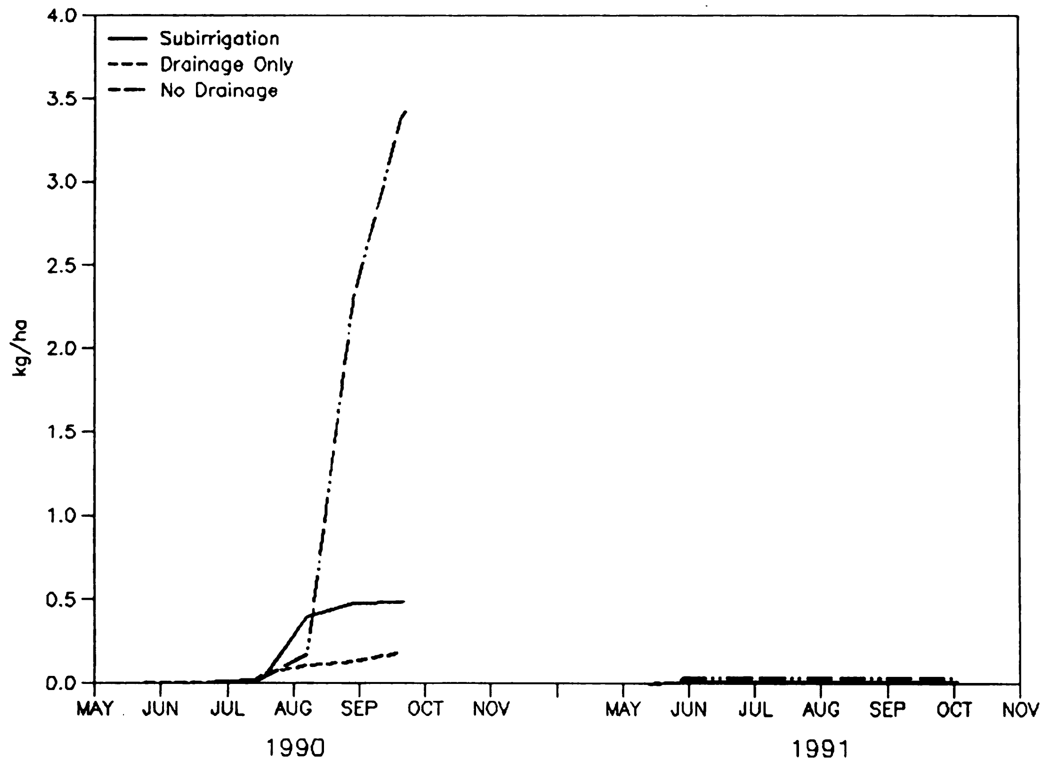

Figure 11. Surface Drainage Nitrate-N Loadings

The accumulated loadings of nitrate nitrogen in surface drainage discharge are shown in Figure 11. The 1990 accumulated nitrate nitrogen loading in surface drainage discharge from the SI treatment was 0.49 kg/ha, 0.18 kg/ha from the DO treatment, and 3.42 kg/ha from the ND treatment tile drainage water. The 1991 SI treatment had accumulated 0.21 kg/ha nitrate nitrogen in surface drainage outflow, the DO treatment had 0.29 kg/ha, and the ND treatment had 0.03 kg/ha. These loadings were much lower than from the 1990 growing season due to the lack of substantial surface drainage outflow.

Jacobs and Gilliam (1985) reported that subsurface drainage substantially reduced surface drainage nitrate nitrogen loadings by 32 fold. Campbell, et al. (1985) reported that controlled drainage had 446% less nitrate nitrogen in surface drainage water than from a water furrow irrigation system surface drainage. Deal, et al. (1986), predicted using DRAINMOD that controlled drainage would increase nitrate nitrogen loadings in surface drainage by 26% compared to conventional subsurface drainage. Deal, et al. (1986), predicted a 26% reduction in nitrate nitrogen loadings in surface drainage from a controlled subsurface drainage treatment compared to a conventional drainage treatment. Evans and Skaggs (1989) predicted a 89% reduction in controlled subsurface drained surface drainage nitrate nitrogen loadings compared to conventional subsurface drainage.

Nitrate nitrogen is a highly soluble mineral and moves into the soil profile quite readily. It was expected that the tile drained treatments would contain substantially less amount of nitrate concentrations in the surface drainage water. The DO treatment most likely leached much of the nitrate nitrogen in the soil profile through the tile drains whereas the SI treatment restricted leaching of nitrate nitrogen into the tile drainage by holding the water in the field. Nitrate nitrogen in the ND treatment either must stay in the soil profile or be removed by surface waters, which would explain the high loadings observed in the surface drainage outflow from the ND treatment.

It is possible that more careful regulation of the water table depth of the subirrigated treatment through opening and closing the headstand gradually can further decrease nitrate concentrations and loadings, particularly in climates the North Central regions of the United States. The total volume of nitrate would be spread over a longer interval with gradual lowering of the water table, thus lessening the concentrations and loading over a single short span of time due to decreased drainage flow rates. This would be important during periods of high rains such as experienced in 1990, as the potential for flushing of nitrates would be high.

Another important consideration would be the lowering of the water table to facilitate harvest. It would be to the farmers advantage to lower the water table gradually beginning late in the growing season and continuing until the desired water table depth is reached. It may be hypothesized that the high initial (April, 1990) concentrations of nitrate found in the DO tile drain outflow resulted from nitrate that was in solution in the soil water and was flushed out in the drainage outflow, which normally accompany the spring thaw and rains. Thus it would appear that control of the drainage during the spring at which time intense drainage flows usually occur might reduce spring discharge nitrate nitrogen loadings.

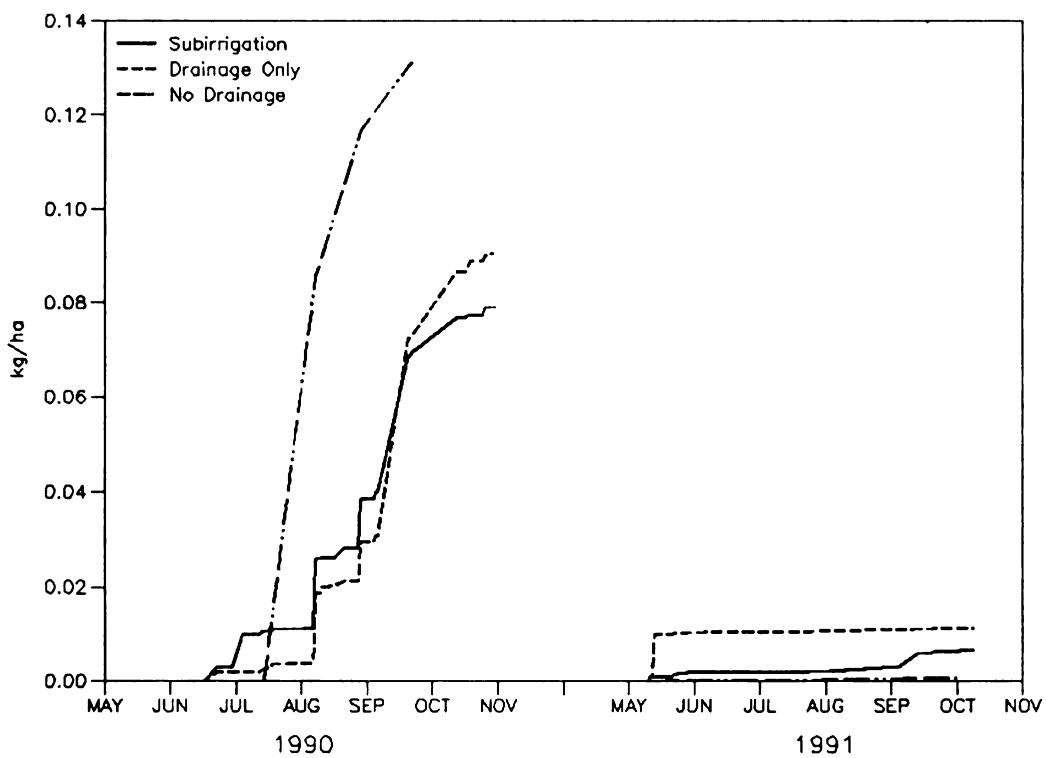

Figure 12. Total Drainage Orthophosphate-P Loadings

The cumulative orthophosphate phosphorus loadings in surface and tile drainage waters from the SI, DO and ND treatments are shown in Figure 12. The 1990 growing season total orthophosphate phosphorus loadings from both surface drainage and tile drainage for the SI treatment was 0.08 kg/ha, and 0.09 kg/ha for the DO treatment. The total orthophosphate phosphorus loadings from the surface drainage of the ND treatment was 0.13 kg/ha. The SI treatment orthophosphate phosphorus loadings in overall drainage waters was 11% less than in the DO treatment drainage waters, and 38% less than from the surface drainage waters in the ND treatment. For the 1990 growing season, in both tile drained treatments, a reduction in orthophosphate phosphorus loadings was observed compared to the treatment with no tile drains.

The 1991 growing season total orthophosphate phosphorus loadings for the SI treatment was 0.006 kg/ha, 0.011 kg/ha for the DO treatment, and 0.001 kg/ha for the ND treatment. Accuracy of such low values is questionable, thus conclusions are impossible to make when comparing these loadings with those found during the 1990 growing season. Baker, et al. (1975) did report loadings of up to three significant factors but these measured values were not used in any comparison study.

Schwab, et al. (1980) reported that subsurface drainage decreased total phosphorus loadings in drainage water by 83% compared to a surface drainage system. Bengtson, et al. (1988) reported that subsurface drainage reduced total phosphorus loadings in drainage water by 56% compared to a surface drainage only treatment. Campbell, et al. (1985),

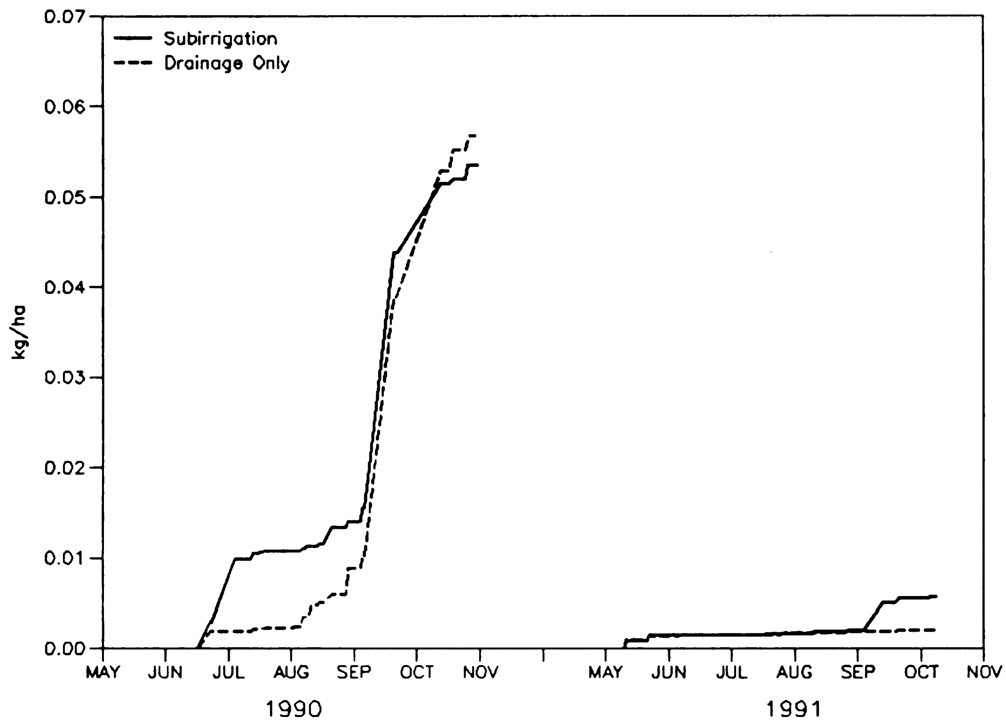

Figure 13. Tile Drainage Orthophosphate-P Loadings

reported that subirrigation reduced total orthophosphate loadings in drainage water by 156%. Deal, et al. (1986), reported that controlled drainage reduced total phosphorus by 4% compared to conventional subsurface drainage. Evans and Skaggs (1989) reported a 53% reduction in controlled drainage phosphorus loadings compared to conventional drainage.

The cumulative orthophosphate phosphorus loadings in tile drainage outflow are shown in Figure 13. The 1990 growing season SI tile drainage outflow had 0.05 kg/ha orthophosphate loadings, and 0.06 kg/ha in the DO tile drainage water. The 1991 cumulative orthophosphate phosphorus loading in the SI tile drainage water was 0.006 kg/ha, and 0.002 kg/ha in the DO treatment. There was very little difference between the SI and DO treatment tile drainage cumulative orthophosphate phosphorus loadings during both growing seasons. Although Figure 13 would suggest that the SI increased tile drainage water loadings of orthophosphate phosphorus compared to the DO treatment, these values are too small to draw definitive conclusions.

Deal, et al. (1986), predicted a 12% decrease in controlled drainage subsurface drainage total phosphorus loadings. Evans and Skaggs (1989) reported a 24% reduction in controlled subsurface drainage phosphorus loadings compared to convectional subsurface drainage.

The cumulative orthophosphate phosphorus loading in surface drainage discharge are shown in Figure 14. The 1990 growing season orthophosphate phosphorus surface drainage loadings from the SI was 0.026 kg/ha, 0.034 kg/ha from the DO treatment, and 0.131 kg/ha from the ND treatment surface drainage water. The 1991 cumulative orthophosphate phosphorus loading in the SI surface drainage water was 0.001 kg/ha, 0.009 kg/ha from the DO treatment, and 0.036 kg/ha from the ND treatment. The 1990 surface drainage orthophosphate phosphorus loadings were highest from all three treatments in August, which is when surface drainage outflow had increased from previous months due to the August high rainfall events. The 1991 surface drainage orthophosphate phosphorus loadings

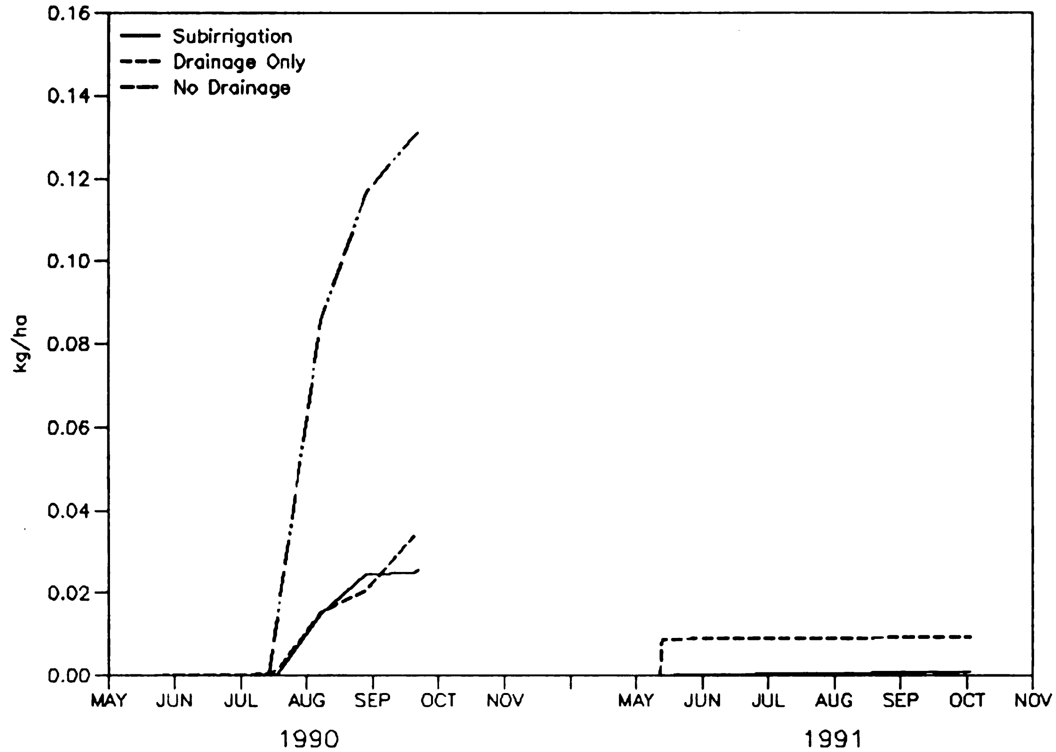

Figure 14. Surface Drainage Orthophosphate-P Loadings

were very low but did tend to be relatively higher during months of increased surface drainage outflow. The orthophosphate phosphorus concentrations and loadings found in the 1990 growing season surface drainage outflow from all three treatments were highest when surface drainage outflow was highest. The 1991 low surface drainage outflows did not show this trend as clearly. Since phosphorus is considered a soil bound nutrient, it is usually lost in highest quantities by surface drainage.

Bengtson, et al. (1988), reported that subsurface drainage reduced total phosphorus loadings in surface drainage water by 66% compared to a surface drainage treatment. Campbell, et al. (1985) reported that subirrigation reduced surface drainage orthophosphate loadings by 323% compared to the furrow irrigation system. Deal, et al. (1986), predicted that controlled drainage would increase surface drainage total phosphorus loadings by 20% compared to conventional drainage. Evans and Skaggs (1989) reported that controlled drainage reduced surface drainage total phosphorus loadings by 71% compared to conventional subsurface drainage. System design and management as described by Evans and Skaggs (1989) affects the amount of surface drainage, and since phosphorus is a soil bound nutrient susceptible to surface leaching, the reduction of surface drainage volumes through proper management can reduce the phosphorus loadings being discharged at edge of field.

Phosphorus is considered to be a difficult mineral to manage in the soil. The total phosphorus amount in an average mineral soil compares favorably with that of nitrogen, however most of the phosphorus present is unavailable to the plant (Lyon et al, 1952). Thus, it is necessary to apply more phosphorus to the soil than the plant can remove. Much of this phosphorus becomes tied up in the soil as either organic or inorganic compounds, or by the active clay fraction of the soil. Rapid decomposition of organic matter and high microbial population in the soil environment results in a temporary tying up of the inorganic phosphorus.

The soil at the site may have several factors working together to make phosphorus susceptible to leaching from the soil profile. As the summer crop grows and is in need of the mineral, both organic decomposition and microbial activity are at high levels rendering the phosphorus temporarily unavailable. At the end of the growing season, the soil temperature drops resulting in a drop in both organic decomposition and microbial activity, which in turn frees up some of the phosphorus that has been inactivated. This process occurs when the crop is no longer growing and therefore the phosphorus is removed by leaching or through runoff and erosion. This trend was observed from all three treatments during the 1990 growing season, but was not clearly shown during the 1991 growing season due to the low drainage volumes. However, the low concentrations in the soil and water suggests leaching of applied phosphorus does not occur significantly.

Total potassium loadings in the tile and surface drainage waters from all three treatments are shown in Figure 15. The 1990 growing season total potassium loadings from both surface and tile drainage for the SI treatment was 4.72 kg/ha, 2.61 kg/ha from the DO treatment, and 1.92 kg/ha from the ND treatment. The SI treatment overall potassium loadings in drainage waters was 45% greater than in the DO treatment drainage waters, and 59% greater than in the ND drainage waters. The 1991 growing season total potassium loadings in

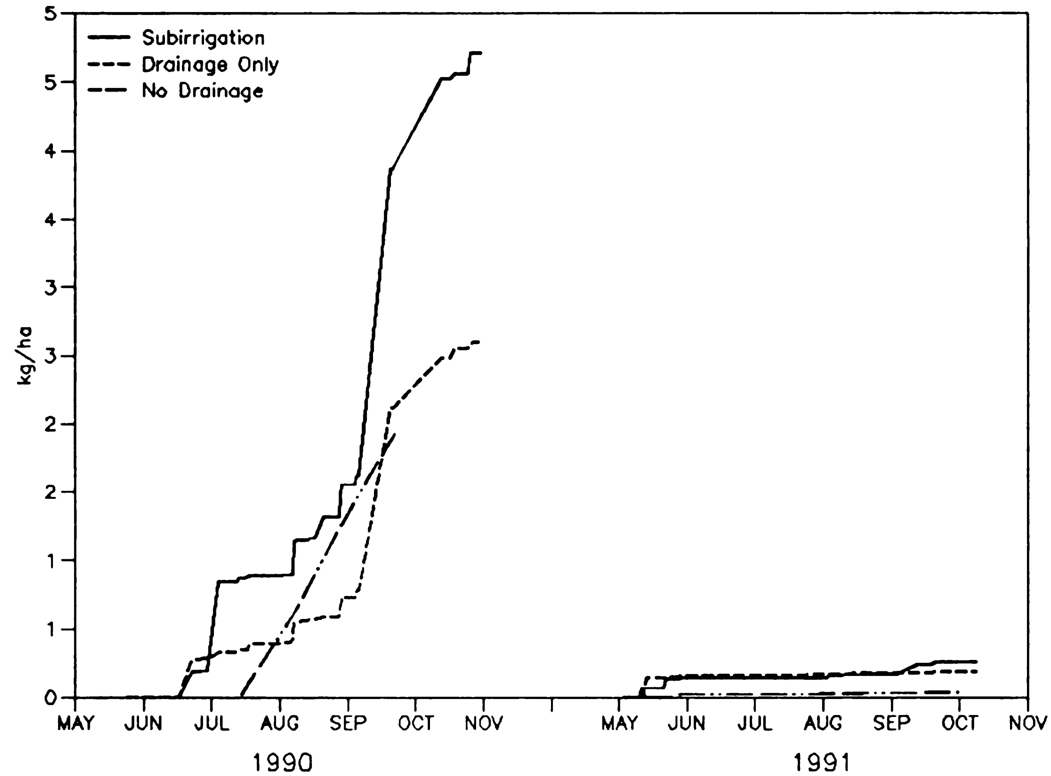

Figure 15. Total Drainage Potassium Loadings

drainage outflow from the SI treatment was 0.27 kg/ha, 0.18 kg/ha from the DO treatment, and 0.04 kg/ha from the ND treatment. The overall potassium loadings in the SI drainage water was 77% greater than in the DO treatment drainage waters, and 85% greater than in the ND drainage waters.

Schwab, et al. (1980) reported that subsurface drainage reduced potassium loadings in drainage water by 42% compared to a treatment that has no subsurface drainage. Bengtson, et al. (1988), reported that subsurface drainage reduced potassium loadings in drainage water by 24% compared to surface drainage only treatments. Both studies attributed the differences in the loadings carried by the surface drainage of the two different drainage treatments, subsurface drainage loadings were found to be less substantial than was found in this study.

Since potassium leaches readily through the soil in larger quantities under saturated conditions, the SI treatment lost more potassium in tile drainage outflow than the DO treatment, and both tile drained treatments increased the loadings of potassium in drainage water compared to the treatment with no tile drains.

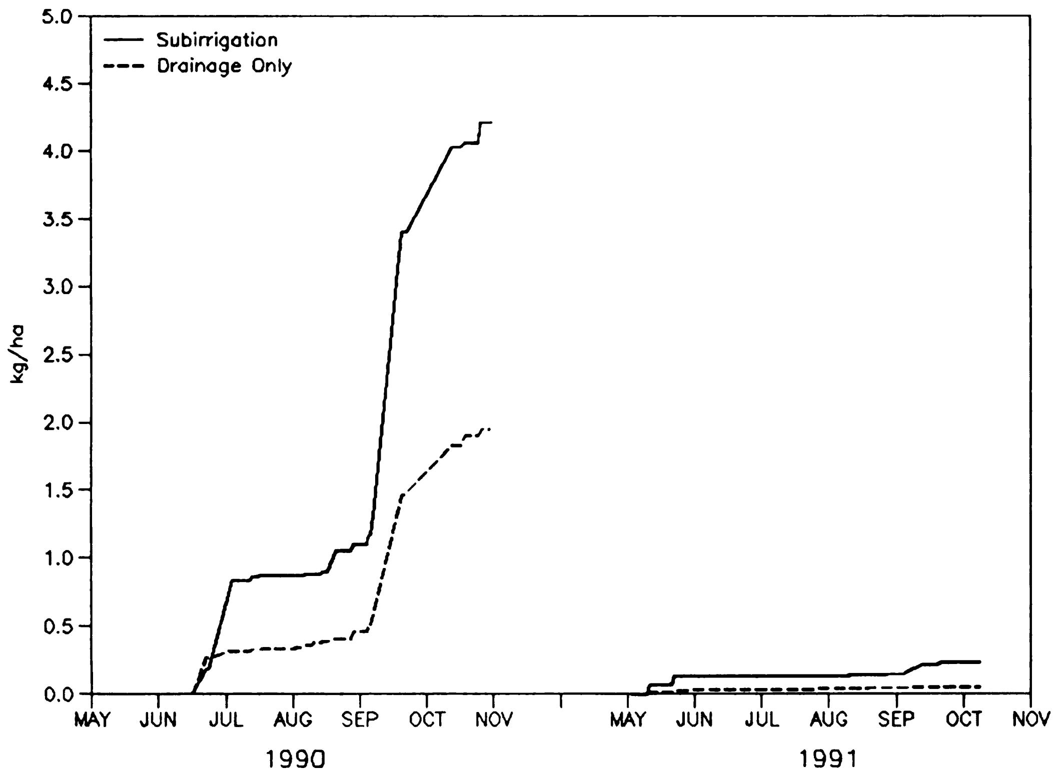

Figure 16. Tile Drainage Potassium Loadings

The cumulative potassium loadings in tile drainage outflow are shown in Figure 16. The 1990 growing season cumulative tile drainage potassium loadings from the SI treatment was 4.22 kg/ha, and 1.96 kg/ha from the DO tile drainage water. The 1991 growing season cumulative potassium loading in the SI tile drainage water was 0.24 kg/ha, and 0.05 kg/ha in the DO tile water. As with the other nutrients taken and analyzed during the 1991 growing season, the potassium loadings in the tile drainage waters are low. For both growing seasons, the highest monthly tile drainage outflow yielded the highest monthly potassium loadings.

The cumulative potassium loadings in surface drainage discharge are shown in Figure 17. The 1990 growing season loadings from the SI treatment was 0.50 kg/ha, 0.65 kg/ha from the DO treatment, and 1.92 kg/ha from the ND treatment. Potassium readily leaches through the soil in large quantities under saturated conditions. The ND treatment had the highest 1990 cumulative surface drainage outflow which resulted in the highest potassium loadings. With the increased surface drainage due to no tile drains, the highest potassium loadings would be expected from the ND treatment.

The 1991 growing season cumulative potassium loadings were very low as compared to 1990. The surface potassium loading in the SI surface drainage water was 0.036 kg/ha, 0.1345 kg/ha

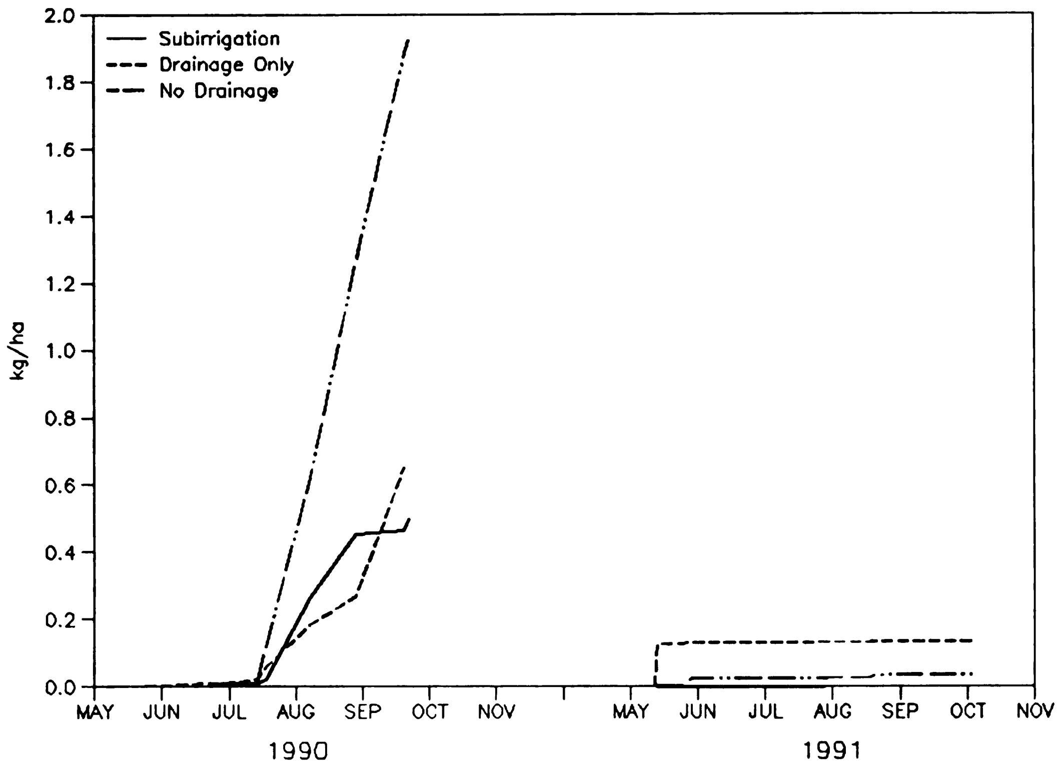

Figure 17. Surface Drainage Potassium Loadings

from the DO treatment, and 0.026 kg/ha from the ND treatment. No correlation can be drawn between surface drainage outflow volumes and the resulting potassium loadings for the 1991 growing season. The highest monthly potassium loading from the DO treatment was greater than 0.13 kg/ha which occurred in May. This was significantly higher than any other 1991 monthly loading measured from all three treatments and may indicate a contaminated sample.

Ammonia nitrogen concentrations and loadings were first monitored in the 1991 growing season. The total accumulated ammonia nitrogen loadings in both tile and surface drainage outflow are shown in Figure 18. The total ammonia nitrogen

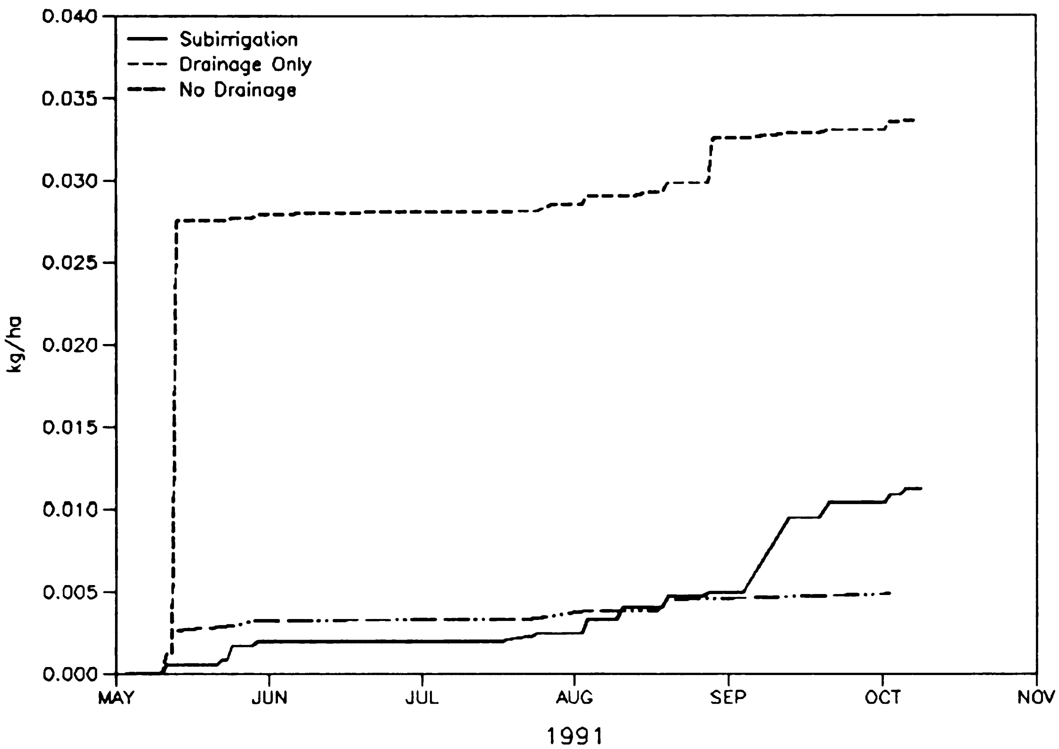

Figure 18. Total Drainage Ammonia-N Loadings

loading from the SI treatment drainage outflow was 0.0111 kg/ha, 0.0336 kg/ha from the DO treatment, and 0.0048 kg/ha from the ND treatment.

The 1991 growing season ammonia nitrogen tile drainage

Table 16. Tile drainage ammonia-N concentrations and loadings

	Subirrigation NH_4-N, ppm					Drainage Only NH_4-N, ppm				
Month	n	Mean	High	Low	kg/ha	n	Mean	High	Low	kg/ha
May	7	.15	.30	.00	.0008	13	.06	.22	.00	.0013
June	21	.17	.90	.00	.0000	21	.27	.97	.00	.0002
July	16	.28	.55	.04	.0003	12	.13	.43	.00	.0004
Aug	11	.25	.37	.19	.0011	9	.33	.66	.22	.0030
Sept	11	.22	.26	.19	.0054	4	.53	.67	.39	.0005
Oct	1	.48			.0003	1	.25			.0001
Total=					.0079					.0055

concentrations and loadings are presented in Table 16 . The cumulative ammonia nitrogen loadings are shown in Figure 19. The SI tile drainage outflow contained 0.008 kg/ha ammonia nitrogen, and the DO tile drainage outflow contained 0.006 kg/ha.

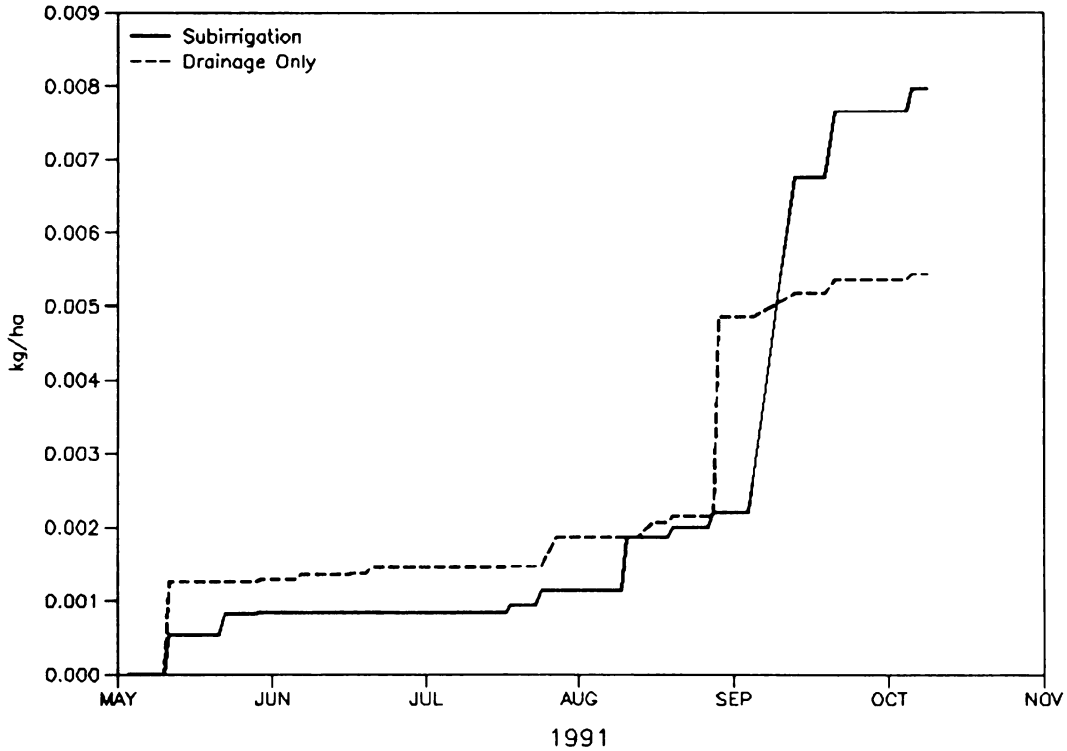

Figure 19. Tile Drainage Ammonia-N Loadings

The 1991 growing season ammonia nitrogen surface drainage concentrations and loadings are presented in Table 17. The cumulative ammonia nitrogen loadings are shown in Figure 20. The cumulative ammonia nitrogen loadings in surface drainage outflow was 0.003 kg/ha, 0.028 kg/ha from the DO treatment, and 0.005 kg/ha from the ND treatment. The high surface drainage ammonia nitrogen loadings in the DO treatment

Table 17. Surface drainage ammonia-N concentrations and loadings

Subirrigation / Controlled Drainage (SI)

NH_4-N, ppm

Month	n	Mean	High	Low	kg/ha
May	4	1.05	0.76	0.31	0.0011
June	0	----	----	----	- -----
July	2	0.15	0.16	0.14	0.0002
Aug	4	0.88	0.27	0.65	0.0014
Sept	0	----	----	----	------
Oct	2	0.76	0.96	0.56	0.0005
Total=					0.0032

Conventional Subsurface Drainage Only (DO)

NH_4-N, ppm

Month	n	Mean	High	Low	kg/ha
May	5	9.64	46.37	0.37	0.0266
June	0	----	-----	----	------
July	2	0.17	0.20	0.13	0.0000
Aug	4	0.50	0.66	0.35	0.0010
Sept	0	----	-----	----	------
Oct	3	0.68	0.81	0.50	0.0005
Total=					0.0281

No Subsurface Drainage (ND)

NH_4-N, ppm

Month	n	Mean	High	Low	kg/ha
May	5	0.75	2.01	0.29	0.0032
June	0	----	----	----	------
July	1	0.18			0.0000
Aug	4	0.47	0.56	0.34	0.0012
Sept	0	----	----	----	------
Oct	4	0.48	0.59	0.34	0.0004
Total=					0.0048

predominantly occurred in May.

Due to many problems encountered with the suction lysimeter used for both growing season, there were very few samples collected. The soil water nutrient concentrations of the samples collected are presented in the raw data form in Appendix D. The soil water data do not show trends that can be attributed to the research treatments.

The soil nutrient laboratory analysis results are presented in Appendix E. The 1990 data includes samples collected from

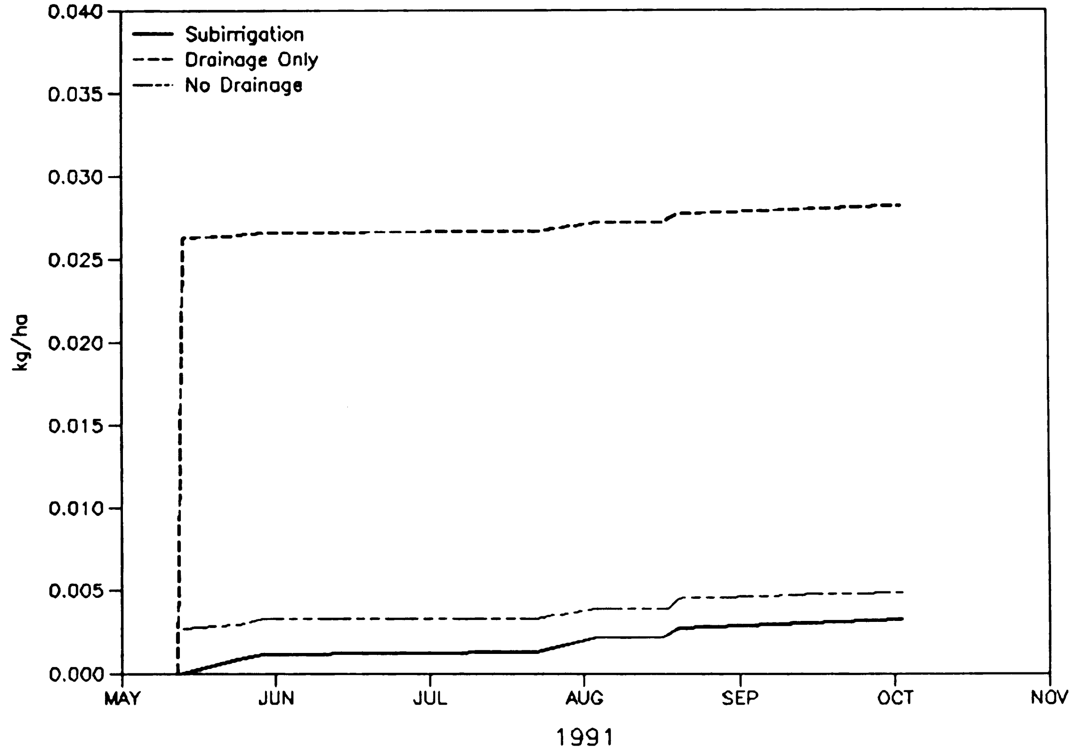

Figure 20. Surface Drainage Ammonia-N Loadings

north and south replications in the SI and DO treatments, and east and west replications in the ND treatment. In 1991, all treatments had a north, south, east and west replication from which soil samples were collected.

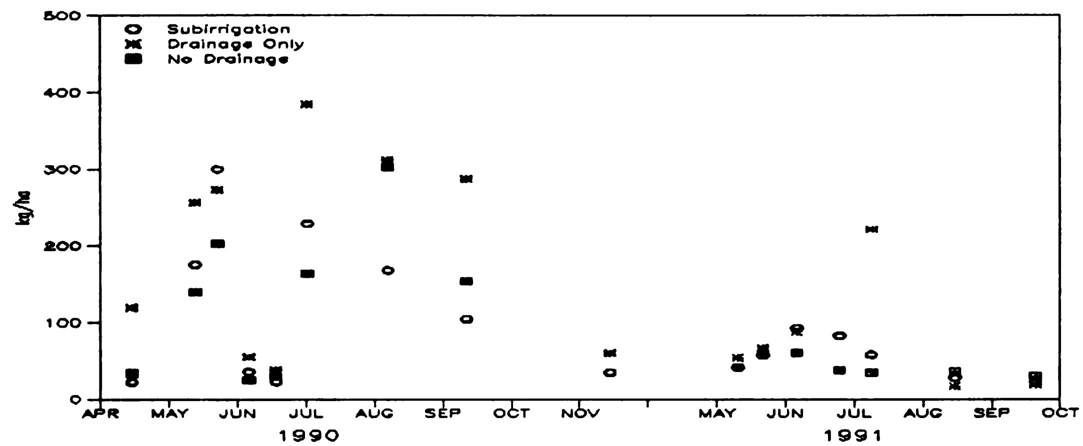

Figure 21. Soil Nitrate Nitrogen Loadings, 0.0-0.3m

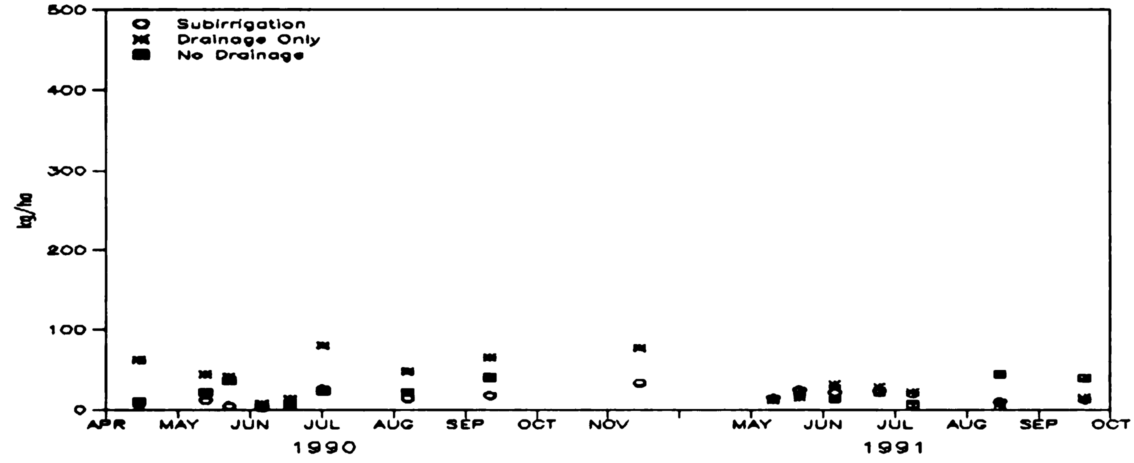

Figure 22. Soil Nitrate Nitrogen Loadings, 0.3-0.6m

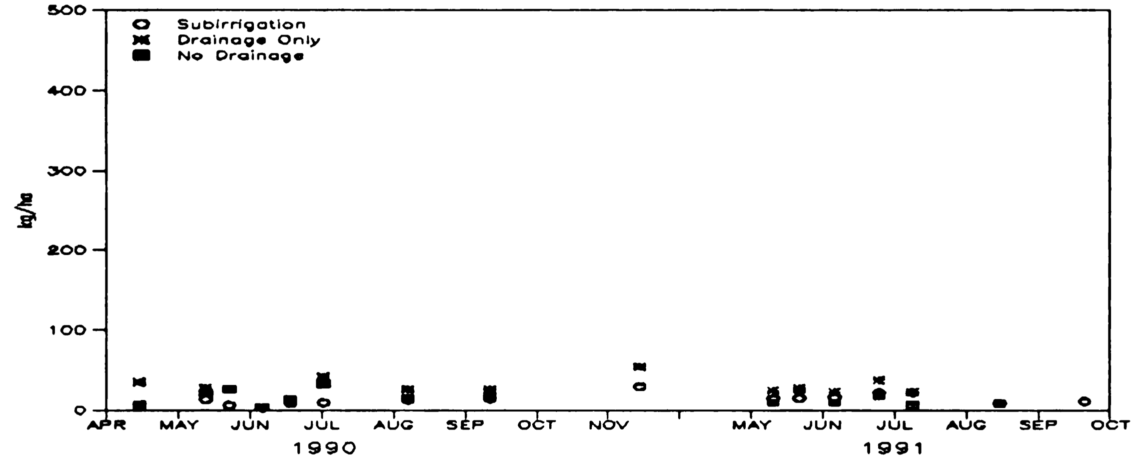

Figure 23. Soil Nitrate Nitrogen Loadings, 0.6-0.9m

The nitrate nitrogen loadings from the soil samples taken over both growing seasons are shown in Figures 21 through 23. These are the average loadings of the replications within each treatment. The 1990 nitrate nitrogen loadings for all three treatments showed an increase in the top 0.3m of soil from April to May, which followed the application of fertilizers and early rain events, with the DO treatment having the highest loadings through most of the year. Samples taken in early and mid-June, 1990, had considerably lower nitrate nitrogen loadings. This may be due to the lack of substantial rainfall during the time those soil samples were obtained. The nitrate nitrogen loadings increased considerably in early July which followed rain events that occurred in late June. As the soil dried up through June, less nitrate nitrogen was available in the top 0.3m of soil. With the rain events in late June, nitrate nitrogen loadings increased in soil samples collected in July, 1990.

There was a small increase in the 1991 nitrate nitrogen soil loadings in the top 0.3m for all three treatments following fertilizer application in late May, but the loadings were considerably less through the 1991 growing season compared to 1990. Rain events immediately followed the application of fertilizers for both growing seasons. However, in 1990, no rain events occurred following the early May rain events until the end of June and early July, which may have prevented further movement of nutrients down to the root zone. During this early development stage of corn, this may prove critical in how much of the nutrients the corn will take up, and how much will remain in the soil. In 1991, there were sporadic rains through May and in early June, and this may have moved more nutrients down to the root zone at a critical time in the corn development when nutrient requirements are high.

Orthophosphate phosphorus loadings from the soil samples are shown in Figures 24 through 26. All three treatments followed

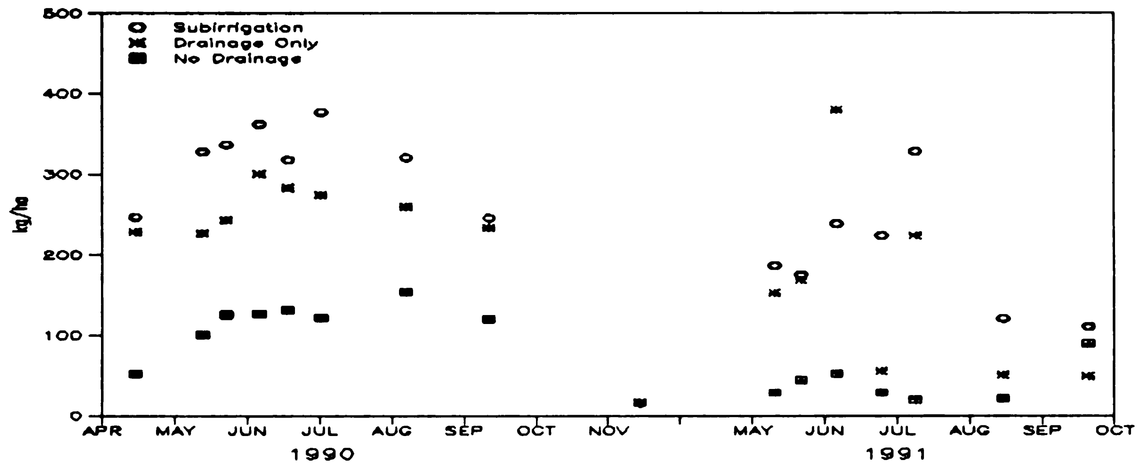

Figure 24. Soil Orthophosphate-P Loadings, 0.0-0.3m

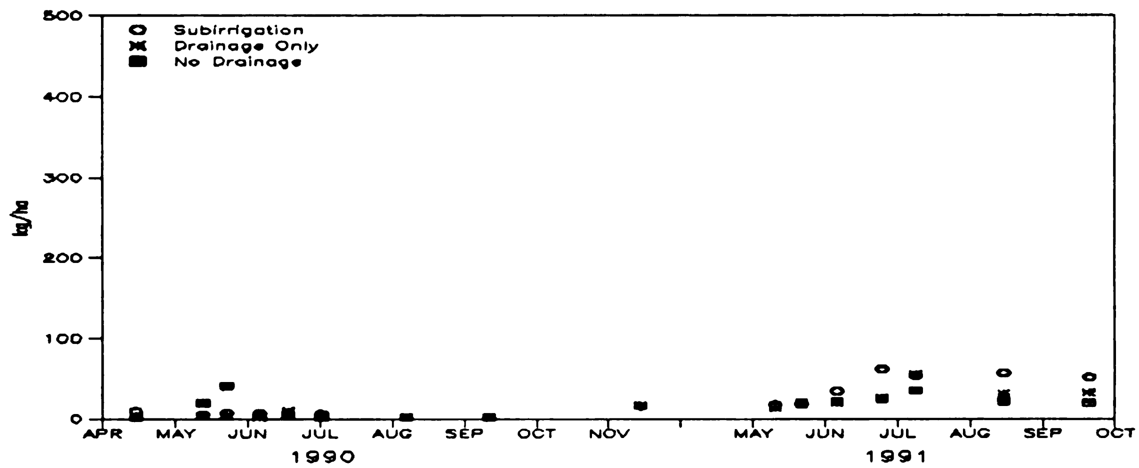

Figure 25. Soil Orthophosphate-P Loadings, 0.3-0.6m

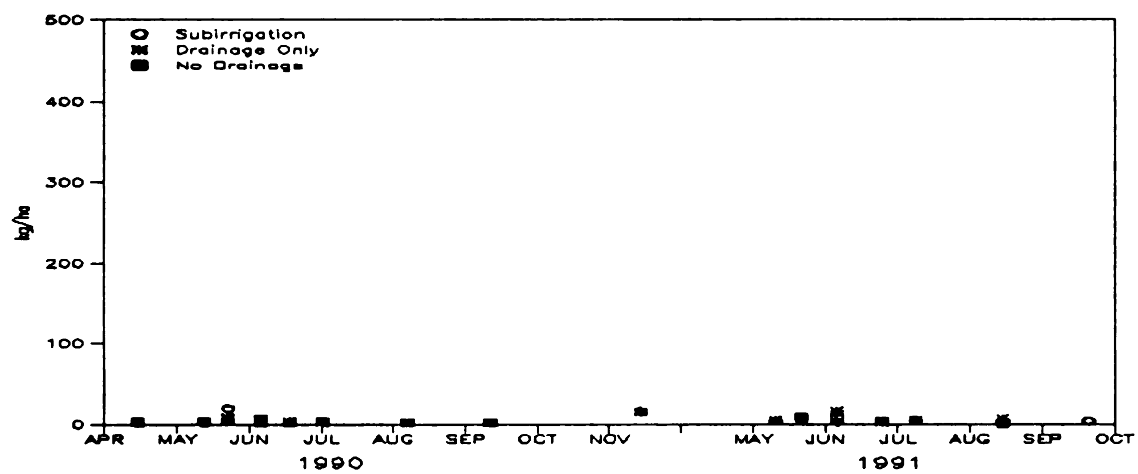

Figure 26. Soil Orthophosphate-P Loadings, 0.6-0.9m

similar trends in the top 0.3m of soil with the tile drained treatments consistently having higher orthophosphate loadings than the ND treatment through most of both growing seasons. The 1990 loadings were slightly higher than in 1991.

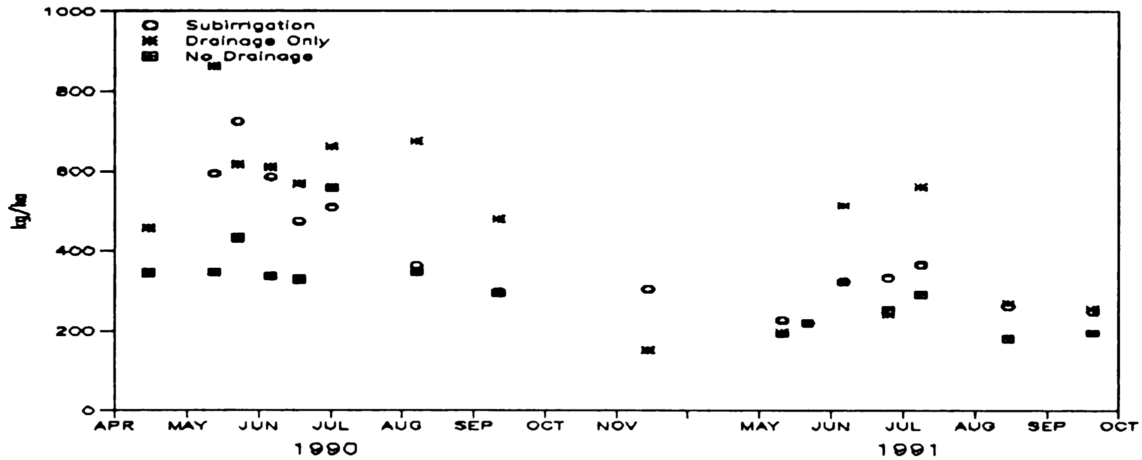

Figure 27. Soil Potassium Loadings, 0.0-0.3m

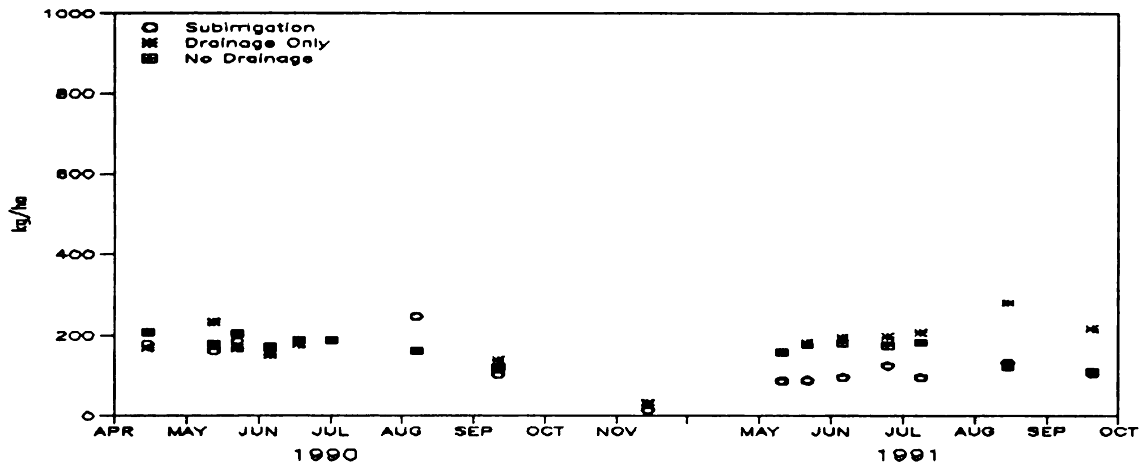

Figure 28. Soil Potassium Loadings, 0.3-0.6m

Potassium loadings from the soil samples are shown in Figures 27 through 29. The soil potassium loadings were slightly lower in 1991 than in 1990. Although the data from the soil samples does not show trends that can be attributed to the treatments or utilization, the nitrate nitrogen,

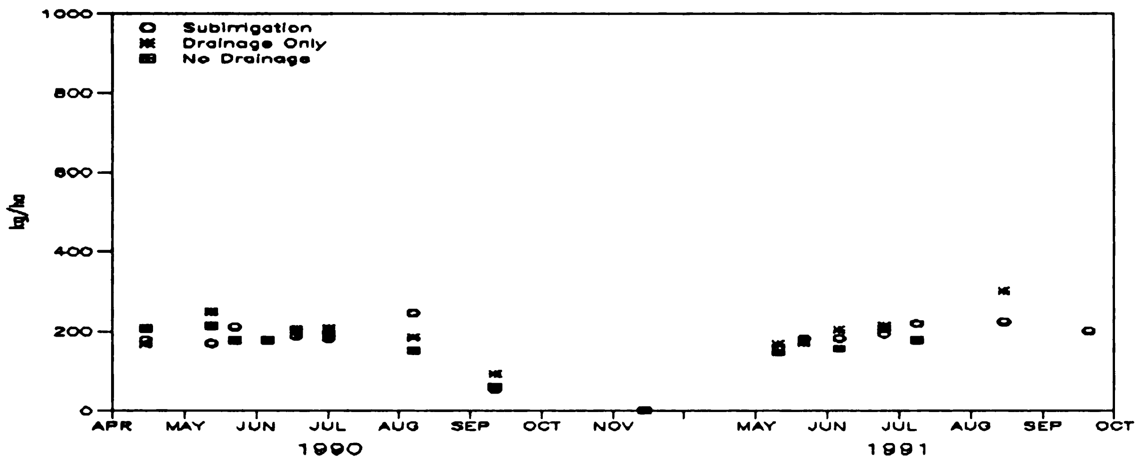

Figure 29. Soil Potassium Loadings, 0.6-0.9m

orthophosphate phosphorus and potassium loadings in the top 0.3m of soil were lower in 1991 than in 1990. This may be due to the sporadic early rains in May and early June following the 1991 fertilizer application, which moved the nutrients to the root zone during a period of high nutrient requirements by the corn. The lack of sporadic rains for over a month following the 1990 fertilizer application may have prevented the movement of fertilizers to the root zone during a critical period of high nutrient requirements for corn.

The 1991 ammonia nitrogen loadings from the soil samples are shown in Figures 30 through 32.

The data from the soil samples does not show trends for nutrient transport that can be attributed to the treatments or utilization. However, the data suggests that nutrient loadings below 0.6m are not substantially measured due to surface application of fertilizers. This is likely due to the

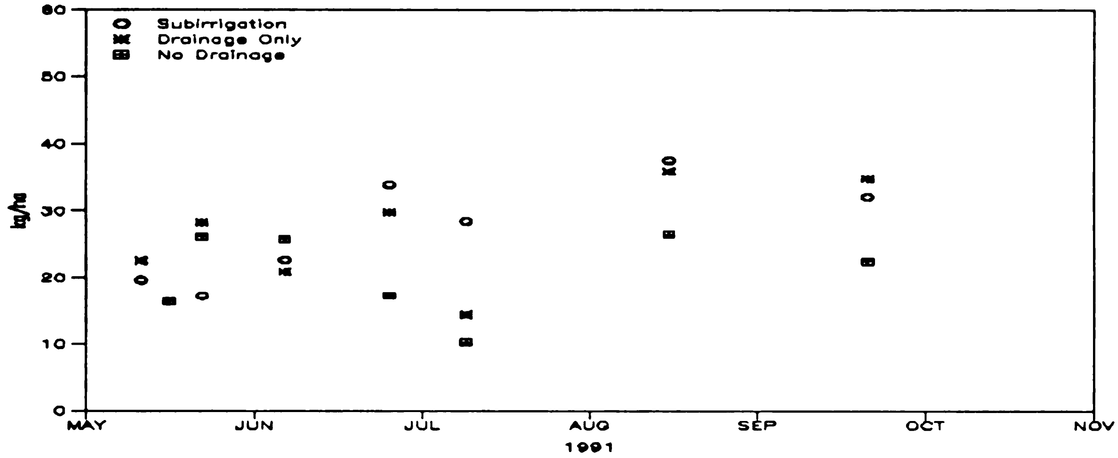

Figure 30. Soil Ammonia Nitrogen Loadings, 0.0-0.3m

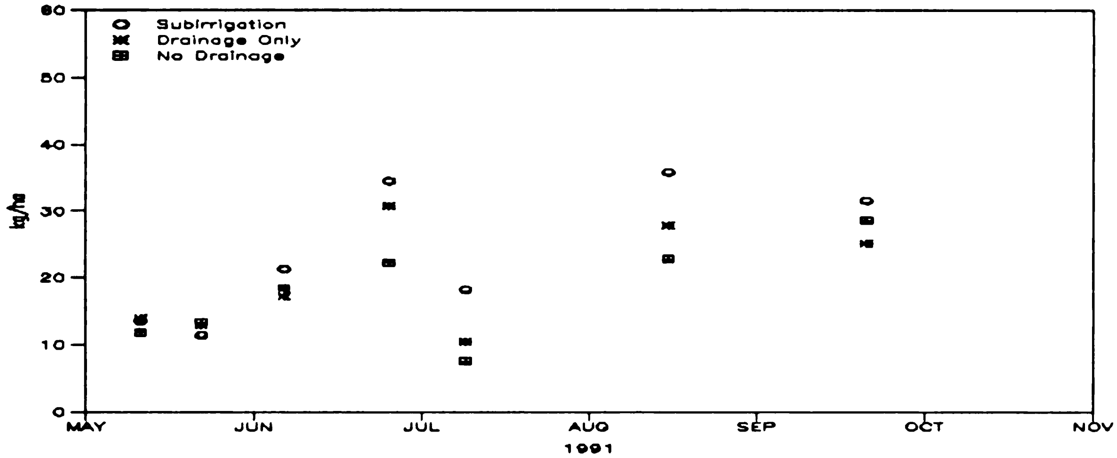

Figure 31. Soil Ammonia Nitrogen Loadings, 0.3-0.6m

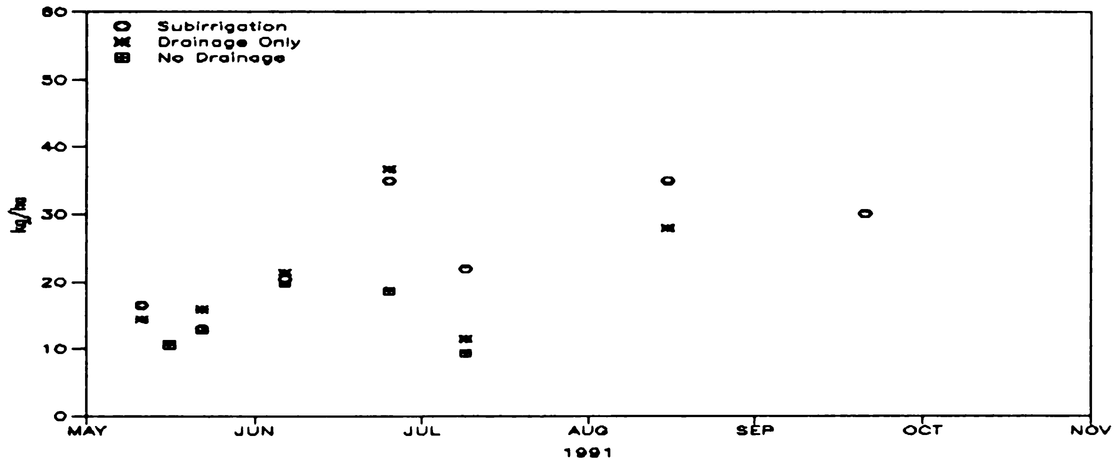

Figure 32. Soil Ammonia Nitrogen Loadings, 0.6-0.9m

soil being very compact with low hydraulic conductivity at the 0.6 to 0.8m depth.

Alachlor

Laboratory analysis data for all soil samples analyzed for alachlor is presented in Appendix F. Limited analysis was performed on the soils due to the high cost of the procedure. Alachlor concentrations in tile and surface drainage water from the treatments are presented in Table 18.

The concentration of alachlor in water samples collected exceeded the Environmental Protection Agency limit of 2 ppb except for the last tile drainage sample analyzed from both

Table 18. Alachlor Loadings and Concentrations in Drainage Water

	SI (ppb)		DO (ppb)		ND (ppb)
Date	Tile	Surface	Tile	Surface	Surface
6/17/91			2.04		
7/18/91			6.20		
7/24/91	4.09	2.24		6.51	9.74
8/10/91				2.38	2.29
8/17/91	2.65		2.55		
8/28/91			1.49		
9/4/91	1.26				

the SI and DO treatment. Due to the low frequency of drainage events during the 1991 growing season, the alachlor remained in the field for most of the growing season. Even late in the growing season, alachlor was still in the tile drainage water of both the SI and DO treatments. The tile drainage sample obtained from the DO treatment on August 28, 1991, was the first sample from that treatment that was below the EPA drinking water standard of 2 ppb for alachlor. The tile drainage sample obtained from the SI treatment on September 4, 1991, was the first sample from that treatment to fall below the EPA standard for alachlor.

The soil samples analyzed showed no detectable levels of alachlor in the top 0.3m of soil for all treatments which is consistent with Smith, et al. (1990). It is interesting to note that the first soil set analyzed (June 7, 1991) for alachlor were collected within 24 hours of herbicide application. It is probable that the granular herbicide had not yet began to react within the soil environment. Between the collection of the soil set taken on June 7, 1991, and the second set analyzed June 25, 1991, 13 mm of rainfall occurred. Yet there was no alachlor detected in the top 0.3m of soil. Sample obtained and tested from the DO tile drainage outflow did contain alachlor, indicating that the some of the alachlor had already been leached to the tile.

Crop Yield and Biomass

Table 19 summarizes the 1990 and 1991 crop yields of all three treatments. The field measurements made to determine the crop grain yields for both growing seasons are presented in Appendix G. Plant emergence for the 1990 growing season in all three treatments was first observed the week of May 22,

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1990. Plant emergence during the 1991 growing season was first observed the week of May 29, 1991. The 1990 SI treatment yield was 2.4 metric tons/ha, 2.2 metric tons/ha from the DO treatment, and 2.1 metric tons/ha from the ND treatment. The 1991 SI treatment yield increased to 3.0 metric tons/ha, but the DO and ND treatment yields decreased to 1.9 metric tons/ha, respectively.

Table 19. Crop Yield Data

Location	Emerged plants/ha	Yield @ 15% M.C. metric tons/ha
1990:		
SI	65,000	2.43
DO	66,500	2.22
ND	67,000	2.08
1991:		
SI	66,300	2.96
DO	66,700	1.87
ND	65,800	1.68

For both growing seasons, the SI treatment created more favorable conditions for growing corn and yields were higher than the other two treatments as shown in Figure 34. The 1990 SI yield was 9% higher than that obtained from the DO treatment, and 17% than that obtained from the ND treatment. The SI and DO treatments were harvested November 8, 1990, and the ND treatment was harvested December 23, 1990, due to the ND area being too wet for field operations before that date. The 1991 SI yield was 58% higher than that obtained from the DO treatment, and 76% higher than that obtained from the ND treatment. All three treatments were harvested on October 8,

1991.

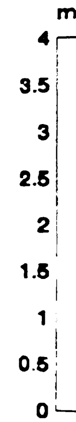

Figure 33.

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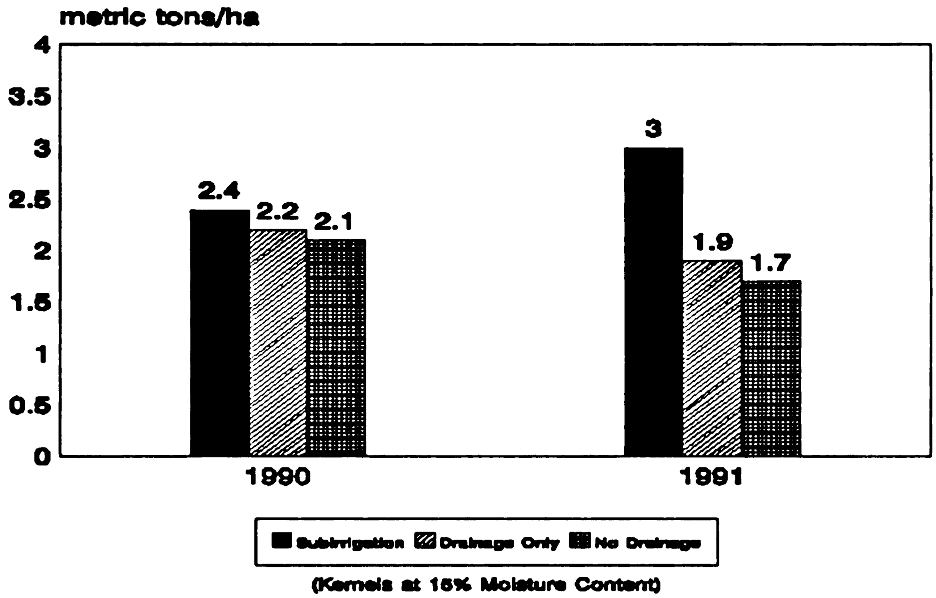

Figure 33. Crop Yields

The 1991 SI treatment yields were the best observed over both growing seasons. The 1990 SI yield was probably reduced (compared to 1991) because of excess water stress. The improved control of water table depth for the SI treatment in 1991 may have utilized the soil water and nutrients in the soil more effectively. Without significant drainage events at the end of the growing season however, it is impossible to determine whether more nutrients were removed from the SI soil profile than in the other treatments, as none of the three treatments showed significant loss of nutrients by the end of the growing season as was observed in 1990.

Foust, et al. (1987) reported than corn silage yields from water table management were highest during periods of drought compar

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compared to periods of excessive rain. Evans and Skaggs (1989) emphasized that water table management systems can significantly increase yields when properly designed and carefully managed, but mismanagement of such systems can significantly reduce crop yield. Belcher (1990) stressed the sensitivity of corn production to the management of the water table depth. Sipp, et al. (1984), and Rausch and Nelson (1984), reported crop yield increases under properly managed water table management systems. Carter, et al. (1988) reported that high water table depths had adversely affected soybean, wheat and corn yields.

The results of the leaf area index measurements are shown in Table 20. The leaf index field measured data are presented in Appendix G. Although the 1990 yields from the SI treatment fared slightly better than the other treatments, there was a slight decrease in leaf area index for plants in the SI treatment compared to plants in the DO and ND. The 1991 leaf area index results show that the SI treatment developed crops in both replications with leaf areas greater than in the other treatments. The decrease in leaf area for the DO and ND treatments resulted from water stress caused by the low rainfall amounts received in 1991. These results were expected since the 1991 crop yield from the SI treatment was much higher than from the other treatments.

The plant biomass production results are presented in Table

Table 2

Date
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6/19/91
7/10/91
7/24/91

Table 20. Leaf Area Index

	SI Leaf Index		DO Leaf Index		ND Leaf Index	
Date	n	m^2/m^2	n	m^2/m^2	n	m^2/m2
7/18/90	70	3.34	70	2.46	70	2.51
8/2/90	70	1.87	70	2.13	70	2.24
6/19/91	70	1.18	70	1.06	70	0.68
7/10/91	70	3.68	70	3.10	70	2.94
7/24/91	70	2.91	70	2.02	70	2.75

21. The 1990 plant biomass was higher in the SI treatment than in the other treatments. This slight increase along with the increase in crop yield suggests that the plants in the SI had better developed plants. The fact that leaf area indexes were slightly lower in the SI treatment may indicate the leaves of all the treatments were damaged during the latter development stages due to the excessive rains of late-July, August and September.

Table 21. Plant Biomass

	SI Plant Biomass		DO Plant Biomass		ND Plant Biomass	
Date	n	kg/ha	n	kg/ha	n	kg/ha
7/18/90	70	583.31	70	405.15	70	371.38
8/2/90	70	1219.75	70	1005.83	70	958.75
6/19/91	70	328.05	70	332.46	70	308.67
7/10/91	70	640.93	70	660.72	70	483.15
7/24/91	70	1011.82	70	1098.30	70	641.96

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Elk, et al. (1966) and Sprague (1977) emphasized the delicate relationship water use and other various environmental factors have on the biomass production, leaf area and crop yield through out the entire growing season. Ritter and Beer (1969) reported that early flooding of corn was most detrimental to crop yield as compared to flooding that may occur later in the growing season. Lal and Taylor (1969) reported that intermittent flooding early in the growing season reduced corn yields compared to water tables that were maintained at constant depths. Alvino and Zerbi (1986), and Baser, et al. (1981), reported increased biomass production and grain yields under shallow water table depths. Follett, et al. (1974) reported that corn biomass production and corn grain yields were lower at high and low water table depth, but maximized at medium water table depths.

The nutrient content of plants sampled are presented in Table 23. In 1990, the plant content of nitrogen, phosphorus and potassium were higher in the SI treatment than in the DO and ND treatments which indicates that the SI treatment created soil conditions that made more nutrients available to the corn. It is important to get water to the crop early in its development in order to help free up some of the unavailable nutrients that were either added by fertilizers or were present before planting. In 1991, the exact opposite trend is observed with plant nutrients. The ND treatment had the highest

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Table 2.

Date	n
7/25/90	2
8/8/90	2
7/11/91	2
7/25/91	2
9/4/91	2

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highest plant nutrient content through out most of the development stages. The reason why the ND treatment had higher plant nutrients may be due to the results found in the nutrient content of the kernels analyzed.

Table 22. Plant Nutrient Content

	SI					DO					ND				
		Ave Plant Weight	kg/ha				Ave Plant Weight	kg/ha				Ave Plant Weight	kg/ha		
Date	n	kg/ha	N	P	K	n	kg/ha	N	P	K	n	kg/ha	N	P	K
7/25/90	2	6997.3	65.1	7.0	88.9	2	4438.9	52.8	4.9	59.0	1	3510.8	19.0	2.1	40.0
8/8/90	2	11475.8	117.1	16.1	199.7	2	7863.6	97.5	7.9	100.7	1	8468.8	80.5	6.8	107.6
7/11/91	2	6395.7	70.3	9.5	70.9	2	6276.5	94.2	12.4	101.4	2	4257.3	93.3	13.1	107.6
7/25/91	2	10780.4	113.4	13.8	128.2	2	10451.9	126.5	22.1	183.0	2	7034.1	115.0	19.8	217.5
9/4/91	2	8665.5	84.6	11.2	104.9	2	6763.4	91.9	14.6	119.2	2	6336.5	124.0	18.0	217.9

The results of the corn kernel nutrient content are presented in Table 24. In 1990, the nutrient content in the kernels sampled from the SI treatment were slightly higher than the other treatments. But in 1991, the SI treatment kernel nutrient content was substantially higher than the other treatments. With the 1991 plant nutrient content being lowest in the SI treatment, it would appear that the corn utilized more nutrients to its kernels while the other treatments did not get the nutrients from the stem and leaves into the developing ears. This was most likely caused by the dry conditions that existed for most of the 1991 growing season in the DO and ND treatments. Rattan and George (1969) found that higher levels of nitrogen, zinc, and copper increased yields under water table management systems with well drained soils. The uptake of N and Zn by corn was reduced by high water able depths a

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Table 23. Corn Kernel Nutrient Content

	SI					DO					ND				
		Ave Kernel Weight	kg/ha				Ave Kernel Weight	kg/ha				Ave Kernel Weight			
kg/ha															
Date	n	kg/ha	N	P	K	n-Rep	kg/ha	N	P	K	n-Rep	kg/ha	N	P	K
8/8/90	1-N	9425.0	126.3	34.9	31.1	1-N	8093.1	118.2	24.3	23.5	1-W	8636.3	113.1	27.6	25.9
	1-S	9327.5	145.5	37.3	35.4	1-N	8525.3	118.5	31.5	31.5	1-E	8770.3	142.1	28.1	27.2
9/4/91	2-N	10347.4	118.7	35.2	27.4	2-N	7148.2	100.1	32.7	24.1	2-N	7491.3	94.3	31.0	22.8
	2-S	12242.3	145.4	43.4	34.1	2-S	7974.7	115.7	33.9	24.7	2-S	6484.6	87.3	24.8	24.8

Statistical Analysis

The results of the 2-sample t-test statistical comparison of the soil nutrient loadings between the three treatment are presented in Appendix H. All tests were run at a significance level of 95%. At the 0.0 to 0.3m soil depth for the 1990 growing season, there was no significant difference found among treatments for the nitrate nitrogen loadings. There was significant difference found between the SI and both DO and ND treatments for orthophosphate phosphorus loadings in the 0.0 to 0.3m depth. Potassium loadings were found to be significantly different at the 0.0 to 0.3m depth between the subsurface drained treatments (SI and DO) compared to the ND treatment.

A 2-sample t-test statistical comparison of the crop yields between the three treatment for are presented in Appendix H. For the 1990 growing season, a comparison was made only between the two subsurface drained treatments because two

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replications of yield were measured (North and south) while the ND treatment had only one yield measurement made by the farmer due to the late harvest.

At a confidence level of 95%, there was no significant difference found between the SI and DO treatment for the 1990 corn grain yields. There was a high significant difference found between the SI treatment compared to both the DO and ND treatments. No significant difference was found between the DO and ND treatments.
The ANOVA tables for leaf index and plant biomass test of significant difference are presented in Appendix H. The test was performed at a 95% confidence level, with a F critical value of 1.31. There was significant difference found between the three treatments for all leaf index and plant biomass measurements made during both growing seasons. The Fischer Protected LSD test found significantly higher peak leaf index in the SI treatment compared to the DO and ND leaf indexes for both growing seasons. No significant difference was found between the DO and ND treatment leaf indexes for both growing seasons.

There was significant difference found between the SI plant biomass and both the DO and ND plant biomass for the 1990 growing season. No significant difference was found between the DO and ND plant biomass. Plant biomass of the SI treatment was found to be significantly higher than the DO treatment a

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treatment at the end of the 1990 growing season. The SI plant biomass was significantly higher than the ND plant biomass for the entire 1990 growing season. The DO plant biomass was not significantly different than the ND plant biomass for the 1990 growing season.

Plant biomass from the SI treatment was found to be significantly lower than the DO plant biomass at the end of the 1991 growing season. This may be due to the increased kernel production observed in the SI treatment. The SI and DO plant biomass was significantly higher than the ND plant biomass for the 1991 growing season.

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CONCLUSIONS

At the Unionville site for the 1990 and 1991 growing seasons:

1. Subirrigation / controlled drainage increased the volume of outflow from the tile compared to conventional subsurface drainage for both above and below average growing season rainfall.

2. Subirrigation / controlled drainage had practically no effect on surface drainage volume compared to conventional subsurface drainage for both above and below average growing season rainfall.

3. Both subirrigation / controlled drainage and conventional subsurface drainage reduced surface drainage compared to the non-tiled treatment for above average growing season rainfall. The subirrigation / controlled drainage had no effect on surface drainage compared to the non-tiled treatment for below average growing season rainfall.

4. The sum of tile outflow discharge and surface drainage for both subirrigation / controlled drainage and conventional subsurface drainage was greater than the surface drainage from the non-tiled treatment for both above and below average growing season rainfall.

5. Tile drainage nitrate nitrogen loading and average monthly concentrations were reduced by subirrigation / controlled drainage for both above and below average growing season rainfall.

6. The surface drainage nitrate nitrogen loading was increased slightly by subirrigation / controlled drainage compared to conventional subsurface drainage for above average growing season rainfall. There was no effect on surface drainage nitrate nitrogen between subirrigation / controlled drainage and conventional subsurface drainage for below average growing season rainfall.

7. The non-tiled treatment surface drainage nitrate nitrogen loading was reduced by both subirrigation / controlled drainage and conventional subsurface drainage for both above and below average growing season rainfall.

8. Tile drainage orthophosphate phosphorus loading and average monthly concentrations were reduced

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slightly by subirrigation / controlled drainage for above average growing season rainfall, but were insignificant for below average growing season rainfall.

9. Surface drainage orthophosphate phosphorus loading was reduced slightly by subirrigation / controlled drainage compared to conventional subsurface drainage for above average growing season rainfall, but were insignificant for below average growing season rainfall.

10. Non-tiled treatment surface drainage orthophosphate phosphorus loading was reduced by both subirrigation / controlled drainage and conventional subsurface drainage for above average growing season rainfall, but were insignificant for below average growing season rainfall.

11. Tile drainage potassium loading and average monthly concentrations were increased by subirrigation / controlled drainage for both above and below average growing season rainfall.

12. Surface drainage potassium loading was reduced slightly by subirrigation / controlled drainage compared to conventional subsurface drainage for above average growing season rainfall. There was little to no effect on surface drainage potassium for below average growing season rainfall.

13. Non-tiled treatment surface drainage potassium loading was reduced by both subirrigation / controlled drainage and conventional drainage for above average growing season rainfall. There was little effect on non-tiled surface drainage potassium loading for below average growing season rainfall.

14. Tile drainage ammonia nitrogen loading and average monthly concentrations were increased by subirrigation / controlled drainage for below average growing season rainfall.

15. The surface drainage ammonia nitrogen loading was decreased by subirrigation / controlled drainage compared to conventional subsurface drainage for below average growing season rainfall.

16. The non-tiled treatment surface drainage ammonia nitrogen loading was reduced by both subirrigation / controlled drainage, but increased by conventional subsurface drainage for below average

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17. Combined tile and surface drainage nitrate nitrogen loading was reduced by subirrigation / controlled drainage compared to conventional subsurface drainage for both above and below average growing season rainfall.

18. Combined tile and surface drainage nitrate nitrogen and potassium loadings for subirrigation / controlled drainage and conventional subsurface drainage were greater than the non-tiled treatment surface drainage nitrate nitrogen and potassium loadings loading for both above and below average growing season rainfall.

19. Combined tile and surface drainage orthophosphate phosphorus loading was approximately equal for subirrigation / controlled drainage and conventional subsurface drainage for above average growing season rainfall.

20. Combined tile and surface drainage orthophosphate phosphorus loadings for subirrigation / controlled drainage and conventional subsurface drainage were less than the non-tiled treatment surface drainage orthophosphate loading for above average growing season rainfall.

21. For all three treatments, nitrate nitrogen, orthophosphate phosphorus and potassium loadings in the soil at and below 0.6m remained relatively constant through out the study period.

22. Tile drainage alachlor loadings were higher from the subirrigation / controlled drainage treatment compared to the conventional subsurface drainage treatment.

23. Surface drainage alachlor loadings were lower from the subirrigation / controlled drainage compared to both conventional subsurface drainage and no subsurface drainage treatments.

24. The combined tile and surface drainage alachlor loadings were higher from the subirrigation / controlled drainage treatment than from the conventional subsurface drainage treatment, which were higher than the surface drainage alachlor loadings from the no subsurface drainage treatment.

25. The subirrigation / controlled drainage grain yield was greater than for conventional drainage

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which was greater than non-tiled treatment yield for both above and below average growing season rainfall.

26. Leaf area was higher in the no subsurface drainage treatment compared to the subirrigation / controlled drainage and conventional subsurface drainage treatments for above average growing season rainfall. For below average growing season rainfall, no subsurface drainage treatment had higher leaf area compared to conventional subsurface drainage, but lower compared to subirrigation / controlled drainage.

27. Stem volume was higher in the subirrigation / controlled drainage treatment compared to the conventional subsurface drainage and no subsurface drainage treatments for above average growing season rainfall. Stem volume was lower in the subirrigation / controlled drainage treatment compared to the conventional subsurface drainage treatment, but higher compared to the no subsurface drainage treatment for below average growing season rainfall.

28. Plant nutrient content increased in the subirrigation / controlled drainage treatment compared to the convectional subsurface drainage and no subsurface drainage treatments for above average growing season rainfall. For below average growing season rainfall, plant nutrient content was lower in the subirrigation / controlled drainage treatment compared to the conventional subsurface drainage and no subsurface drainage treatments.

29. Corn kernel yield and quality was increased by the subirrigation / controlled drainage treatment compared to the conventional subsurface drainage and no subsurface drainage treatments for above and below average growing season rainfall.

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RECOMMENDATIONS

Through water table management, control and regulation of water table depth allows for better management of soil and nutrient loss associated with surface runoff. Nutrients such as nitrate nitrogen and orthophosphate phosphorus can be reduced in subsurface drainage discharge through controlled drainage practices. It has also been shown that water table management can increase crop yields especially during periods of below average growing season rainfall.

There are many alternative management schemes that can be used by the farmer in water table management in order to best meet the cropping requirements for the producer. The farmer must be made aware of the critical times when drainage can pose the highest pollution potential to receiving waters and what sort of management decisions can be implemented to minimize the risk of pollution while not seriously endangering the quality of the crop.

Climatological factors had a tremendous affect on the overall performance of the different drainage practices researched. Under proper management, a well designed controlled drainage and subirrigation system has the potential of dramatically reducing accumulative plant nutrients and substantially increasing crop yield. Studies continue to show that in addition to design and management factors, site characteri

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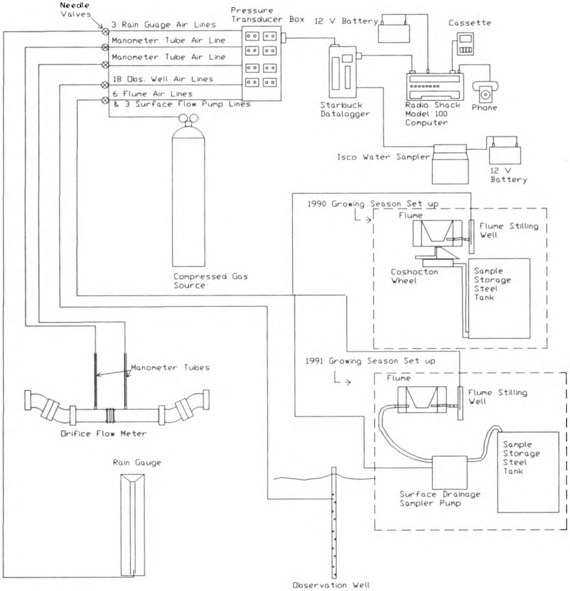
characteristics influence the capability of operating a water table management system without posing a serious pollution threat to receiving waters.

Further research is needed to better understand the impacts different water table management schemes have on the environment. Research must continue to be directed towards developing models that are capable of providing environmentally and economically sound recommendations based on site specific characteristics. Farmers then can use these recommendations towards making critical operation decisions that will allow the operation of water table management systems with minimal environmental impacts.

The research performed supports the need to classify water table management systems as a conservation practice and a best management practice. As the potential use and benefits from water table management systems is further realized by researchers and farmers, it is important that research is continued towards identifying acceptable and practical agricultural production drainage practices which are economically beneficial while not detrimental to the fragile ecology that we exist within.

APPENDIX A

Monitoring Equipment Diagram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Manometer Tube Air Line
Manometer Tube Air Line
18 Obs. Well Air Lines
6 Flume Air Lines
& 3 Surface Flow Pump Lines
Pressure Transducer Box
12 V Battery
Cassette
Starbuck Datalogger
Radio Shack Model 100 Computer
Phone
Isco Water Sampler
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1991 Growing Season Set up
Flume
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Sample Storage Steel Tank
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Orifice Flow Meter
Rain Gauge
Observation Well

Regressions for 1990 watertable observation wells, flumes, orifice meters and rain gages

ID	Tmt	Transducer No.	Regression Equation	R^2	n
Orifice:					
O1Hd1	DO	7	y = 112.7 + 7.41 * x	0.969	6
O1Hd2	DO	8	y = 100.7 + 7.83 * x	0.975	6
O2Hd3	SI	7	y = 138.7 + 6.49 * x	0.955	6
O2Hd4	SI	8	y = 117.5 + 6.65 * x	0.976	6
Flumes:					
FHd1	SI	6	y = 23.0 + 0.75 * x	0.993	6
FHd2	SI	7	NOT OPERATING PROPERLY		
FHd3	DO	6	y = 39.7 + 2.12 * x	1.000	6
FHd4	DO	7	y = 40.0 + 2.00 * x	0.876	6
FHd5	ND	6	y = 32.1 + 1.06 * x	0.990	6
FHd6	ND	7	y = 52.0 + 2.00 * x	0.990	6
Observation Wells:					
OWAHd1	SI	2	y = 53.4 - 0.20 * x	0.939	5
OWAHd2	SI	2	y = 58.4 - 0.21 * x	0.890	5
OWAHd3	SI	2	y = 60.1 - 0.24 * x	0.999	5
OWAHd4	SI	2	y = 56.6 - 0.22 * x	0.999	5
OWAHd5	SI	2	NOT OPERATING PROPERLY		
OWAHd6	SI	3	y = 55.8 - 0.24 * x	0.860	5
OWBHd1	DO	3	NOT OPERATING PROPERLY		
OWBHd2	DO	3	y = 60.4 - 0.21 * x	0.899	4
OWBHd3	DO	3	y = 71.1 - 0.61 * x	0.988	4
OWBHd4	DO	3	y = 58.6 - 0.47 * x	0.998	4
OWBHd5	DO	4	y = 54.2 - 0.17 * x	0.948	4
OWBHd6	DO	4	NOT OPERATING PROPERLY		
OWCHd1	ND	4	y = 55.7 - 0.21 * x	0.910	3
OWCHd2	ND	4	NOT OPERATING PROPERLY		
OWCHd3	ND	4	NOT OPERATING PROPERLY		
OWCHd4	ND	5	NOT OPERATING PROPERLY		
OWCHd5	ND	5	y = 70.2 - 0.26 * x	0.933	3
OWCHd6	ND	5	NOT OPERATING PROPERLY		
Rain Gages:					
RG1	SI	6	y = 23.1 + 8.20 * x	0.993	6
RG2	DO	6	y = 39.4 + 9.41 * x	0.912	6
RG3	ND	8	NOT OPERATING PROPERLY		

where: y = depth of water in column being measured, inches
x = pressure transducer reading
r^2 = correlation coefficient squared
n = number of observations

note: for observation wells, y = elevation of water below ground surface level, inches

Regressions for 1991 watertable observation wells, flumes, orifice meters and rain gages

ID	Tmt	Transducer No.	Regression Equation	R^2	n
Orifice:					
O1Hd1	DO	7	y = 86.5 + 8.54 * x	1.000	6
O1Hd2	DO	8	y = 15.5 + 11.61 * x	0.985	6
O2Hd3	SI	7	y = 91.5 + 10.32 * x	0.994	6
O2Hd4	SI	7	y = 102.0 + 10.21 * x	0.996	6
Flumes:					
FHd1	SI	6	y = 12.5 + 10.46 * x	1.000	6
FHd2	SI	7	y = 12.5 + 10.82 * x	1.000	6
FHd3	DO	6	y = 12.5 + 10.68 * x	1.000	6
FHd4	DO	7	y = 15.5 + 10.89 * x	0.999	6
FHd5	ND	6	y = 36.5 + 9.46 * x	0.995	6
FHd6	ND	7	y = 31.3 + 8.36* x	1.000	6
Observation Wells:					
OWAHd1	SI	2	y = 72.1 + -0.32 * x	0.939	6
OWAHd2	SI	2	y = 65.4 + -0.81 * x	0.890	5
OWAHd3	SI	2	y = 66.0 + -0.16 * x	0.999	3
OWAHd4	SI	2	y = 58.6 + -0.19 * x	0.999	7
OWAHd5	SI	2	y = 58.2 + -0.19 * x	0.817	6
OWAHd6	SI	3	y = 63.3 + -0.37 * x	0.894	5
OWBHd1	DO	3	y = 61.1 + -0.18 * x	0.994	8
OWBHd2	DO	3	y = 55.3 + -0.16 * x	0.899	6
OWBHd3	DO	3	y = 54.7 + -0.11 * x	0.988	6
OWBHd4	DO	3	y = 58.5 + -0.16 * x	0.998	6
OWBHd5	DO	4	y = 54.0 + -0.15 * x	0.948	6
OWBHd6	DO	4	NOT OPERATING PROPERLY		
OWCHd1	ND	4	NOT OPERATING PROPERLY		
OWCHd2	ND	4	y = 55.8 + -0.11 * x	0.930	3
OWCHd3	ND	4	y = 54.8 + -0.82 * x	0.830	3
OWCHd4	ND	5	y = 60.2 + -0.21 * x	0.986	3
OWCHd5	ND	5	y = 65.4 + -0.20 * x	0.933	3
OWCHd6	ND	5	NOT OPERATING PROPERLY		
Rain Gages:					
RG1	SI	6	y = 16.0 + 9.50 * x	0.997	4
RG2	DO	6	y = 33.0 + 9.00 * x	0.998	4
RG3	ND	6	NOT OPERATING PROPERLY		

where: y = depth of water in column being measured, inches
x = pressure transducer reading
r^2= correlation coefficient squared
n = number of observations

note: for observation wells, y = elevation of water below ground surface, inches

APPENDIX B

Climatological Data

1990

DATE

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31 OC
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24 OCT
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20 SEP

1990 UNIONVILLE WEATHER DATA

DATE	AIR TEMP MAX C	AIR TEMP MIN C	AIR TEMP AVG C	GRD TEMP C	RAIN mm	SOLAR MJ
31 OCT 90	16.01	-1.13	6.93	39.78	0	8.38
30 OCT 90	14.94	.9057	7.22	39.11	0	8.577
29 OCT 90	10.64	-4.52	3.08	38.49	0	11.94
28 OCT 90	6.22	2.363	3.816	38.52	0	3.52
27 OCT 90	15.77	-.338	7.32	37.08	0	9.146
26 OCT 90	7.949	-3.71	2.48	37.08	0	11.55
25 OCT 90	8.656	2.73	4.47	40.08	0	7.71
24 OCT 90	11.31	.841	5.85	40.19	0	5.85
23 OCT 90	13.03	-2.747	4.866	39.46	0	11.82
22 OCT 90	13.31	1.99	7.92	40.51	0	9.41
21 OCT 90	15.88	5.806	10.31	38.65	0	4.73
20 OCT 90	16.61	-.235	7.01	37.92	0	12.75
19 OCT 90	9.69	.745	4.37	30.94	0	9.14
18 OCT 90	19.46	3.88	9.91	12.61	5	2.75
17 OCT 90	25.26	10.38	17.37	11.54	7	11.55
16 OCT 90	18.34	1.83	9.42	10.48	0	13.24
15 OCT 90	14.7	4.979	10.11	10.94	0	13.72
14 OCT 90	19.65	3.45	10.41	10.32	12	9.758
13 OCT 90	14.7	-.2355	6.05	10.03	0	11.26
12 OCT 90	13.06	.8798	6.35	10.4	0	9.06
11 OCT 90	14.45	4.488	8.4	10.59	0	13.25
10 OCT 90	12.57	6.477	8.11	10.63	44	1.09
09 OCT 90	7.83	6.24	7	11.38	20	2.09
08 OCT 90	12.7	6.1	8.47	12.82	5	5.66
07 OCT 90	14.37	8.72	10.89	14.38	3	2.97
06 OCT 90	26.79	13.21	19.76	14.52	0	15.27
05 OCT 90	24.28	9.59	16.08	13.26	0	15.48
04 OCT 90	19.59	9.275	13.53	13.92	15	12.88
03 OCT 90	22	6.64	14.7	12.62	15	6.66
02 OCT 90	21	3.477	11.7	12.27	0	16.64
01 OCT 90	15.97	2.55	8.475	12.65	1	5.68
30 SEP 90	13.92	4.86	10.33	14.02	3	7.54
29 SEP 90	18.81	11.55	13.36	14.41	0	10.99
28 SEP 90	19.54	8.93	13.45	14.25	0	12.09
27 SEP 90	25.6	6.2	14.6	13.62	0	16.89
26 SEP 90	17.03	8.39	13.06	13.69	0	6.77
25 SEP 90	21.49	9.49	14.51	12.76	0	14.84
24 SEP 90	18.95	2.01	9.94	12.08	0	14.02
23 SEP 90	11.22	6.798	8.306	13.09	1	7.09
22 SEP 90	16.92	8.121	12.27	14.22	0	12.82
21 SEP 90	14.79	9.22	12.62	14.68	7	2.265
20 SEP 90	22.88	10.09	12.5	14.3	0	19.07

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19 SEP 90	15.53	5.506	12.5	14.3	8	6.05
18 SEP 90	19.03	.623	9.23	14.1		
17 SEP 90						
16 SEP 90	15.97	7.751	11.86	16.15	2	17.3
15 SEP 90	13.87	10.07	11.76	17.25	1	5.22
14 SEP 90	24.82	12.69	18.5	19.14	20	5.38
13 SEP 90	28.36	15.71	21.43	18.98	0	14.27
12 SEP 90	29.05	12.08	19.34	18.3	0	18.53
11 SEP 90	23.77	9.238	16.78	18.7	0	18.51
10 SEP 90	28.24	16.45	20.82	18.89	0	16.52
09 SEP 90	27.1	12.8	18.74	18.12	0	17.79
08 SEP 90	24.97	6.533	15.16	17.78	0	21.7
07 SEP 90	20.54	10.56	17.03	19.34	6	5.764
06 SEP 90	24.08	16.37	19.53	19.78	76	3.492
05 SEP 90	26.34	17.14	22.15	19.73	0	18.99
04 SEP 90	28.34	11.84	19.63	18.63	0	15.67
03 SEP 90	23.56	10.99	16.31	19.11	0	20.36
02 SEP 90	26.38	12.77	19.38	19.85	0	22.48
01 SEP 90	28.98	15.5	21.81	19.57	0	17.13
31 AUG 90	28.45	11.21	19.63	19.28	0	18.4
30 AUG 90	26.06	10.36	18.12	19.54	0	22.97
29 AUG 90	26.1	12.66	19.36	20.64	0	20.61
28 AUG 90	30.94	17.3	23.72	21.17	1	15.01
27 AUG 90	31.29	18.44	24.8	20.49	48	20.89
26 AUG 90	29.63	16.86	21.96	19.95	1	14.76
25 AUG 90	28.62	16.37	22.21	19.52	0	20.63
24 AUG 90	28.6	14	21.09	18.85	0	22.17
23 AUG 90	24.7	17.62	19.94	18.5	0	7.653
22 AUG 90	22.17	15.27	18.39	18.11	0	9.233
21 AUG 90	21.22	16.16	17.91	17.97	0	6.408
20 AUG 90	19.3	14.18	16.47	17.98	0	6.017
19 AUG 90	18.48	14.35	16.14	19.42	23	3.699
18 AUG 90	28.98	18.31	22.43	19.96	11	16.11
17 AUG 90	27.65	16.11	21.47	19.58	0	14.97
16 AUG 90	29.14	17.81	22.44	19.09	0	17.29
15 AUG 90	26.91	14.4	19.77	18.03	1	14.02
14 AUG 90	24.96	9.383	17.08	17.74	0	25.46
13 AUG 90	21	11.98	17.92	18.72	0	11.12
12 AUG 90	24.07	13.98	18.36	18.78	3	10.25
11 AUG 90	24.91	15.16	20.01	19.1	0	20.55
10 AUG 90	28.1	13.11	20.9	18.83	0	25.25
09 AUG 90	28.41	11.92	20.31	18.31	0	25.84
08 AUG 90	26.61	9.572	17.85	17.89	0	24.73
07 AUG 90	23.32	11.41	17.34	17.86	0	24.42
06 AUG 90	17.66	14.95	15.9	18.61	22	7.679
05 AUG 90	22.86	15.9	19.71	19.46	6	10.52
04 AUG 90	20.54	17.84	19.35	19.68	53	2.506
03 AUG 90	28.5	11.89	20.46	19.5	0	20.23

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02 AUG 90 28.78	10.61	20.11	18.93	0	27.15
01 AUG 90 26.93	7.872	17.87	18.45	0	27.91
31 JUL 90 22.38	10.75	17.65	19.61	0	23.13
30 JUL 90 25.77	18.12	21.44	21.31	6	12.7
29 JUL 90 29.73	16.45	23.51	21.31	0	15.86
28 JUL 90 31.57	17.36	24.08	20.82	0	22.63
27 JUL 90 30.31	13.21	21.68	20.06	0	21.89
26 JUL 90 29.22	13	21.11	19.9	0	24.76
25 JUL 90 27.98	12.57	20.62	19.58	0	28.1
24 JUL 90 27.02	11.1	19.21	19.07	0	28.43
23 JUL 90 25.54	10.67	17.65	18.78	0	21.36
22 JUL 90 21	12.97	17.36	19.76	2	9.974
21 JUL 90 27.1	14.33	20.14	20.31	0	23.49
20 JUL 90 25.05	17.44	20.88	20.63	2	16.46
19 JUL 90 29.96	15.59	21.87	20.17	0	22.09
18 JUL 90 28.62	16.8	20.43	20.91	35	10.6
17 JUL 90 29.67	17.08	23.19	20.67	0	22.79
16 JUL 90 26.77	14.12	20.28	19.64	0	23.81
15 JUL 90 26.72	16.07	19.87	19.55	22	16.16
14 JUL 90 18.3	14.83	16.42	20.12	3	4.194
13 JUL 90 24.34	12.08	17.79	21.02	0	24.55
12 JUL 90 22.67	14.52	17.84	21.34	0	29.21
11 JUL 90 25.5	14.28	18.41	22.19	0	15.68
10 JUL 90 26.79	14.52	20.35	22.63	0	29.18
09 JUL 90 29.12	17.02	23.19	22.08	0	27.18
08 JUL 90 32.42	15.16	22.47	21.39	6	14.52
07 JUL 90 25.78	6.734	17.35	21.74	0	23.38
06 JUL 90 22.22	11.3	17.73	22.77	0	30.56
05 JUL 90 29.69	15.4	20.45	23.89	0	23.97
04 JUL 90 34.97	21.3	27.73	23	0	26.82
02 JUL 90 31.92	-112.5	20.14	21.01	0	5.87
01 JUL 90 23.21	14.88	18.7	20.61	0	25.84
30 JUN 90 28.93	15.51	21.28	20.42	5	23.03
29 JUN 90 28.13	16.76	21.98	19.9	11	21.34
28 JUN 90 23.35	13.52	18.28	19.89	0	12.8
27 JUN 90 26.72	13.11	18.74	19.21	0	27.5
26 JUN 90 26.19	15.96	20.29	19.13	1	14.89
25 JUN 90 28.08	7.934	18.95	18.06	0	28.46
24 JUN 90 23.06	12.87	17.18	16.85	0	29.18
23 JUN 90 17.01	13.55	15.24	17.74	8	3.391
22 JUN 90 21.13	14.87	17.94	20.12	19	4.721
21 JUN 90 28.9	16.36	22.08	20.31	0	28.15
20 JUN 90 25.39	12.07	18.59	20.4	0	11.1
19 JUN 90 23.99	11.8	16.81	20.47	0	28.85
18 JUN 90 27.28	13.38	22.58	21.89	0	20.62
17 JUN 90 33.64	19.15	26.1	21.43	0	18.32
16 JUN 90 28.38	15.11	21.57	21.24	0	21.22

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15 JUN 90	27.99	16.73	22.04	20.62	0	30.16
14 JUN 90	29.42	18.06	23.88	20.39	0	18.04
13 JUN 90	33.48	17.24	24.67	18.02	0	23.75
12 JUN 90	20.34	12.43	16.49	18.16	2	6.113
11 JUN 90	23.41	13.5	18.52	19.18	0	27.77
10 JUN 90	23.07	14	18.17	18.8	0	23.78
09 JUN 90	26.9	16.34	20.72	19.13	0	23.88
08 JUN 90	25.13	14.13	19.07	18.87	0	19.29
07 JUN 90	25.97	10.26	19.29	17.9	0	30.22
06 JUN 90	26.05	13.64	19.51	16.34	0	25.58
05 JUN 90	21.73	4.072	14.11	15.86	0	20.9
04 JUN 90	18.1	6.151	11.42	15.87	0	25.14
03 JUN 90	25.18	8.72	17.52	17.81	0	20.42
02 JUN 90	30.05	18.92	23.75	18.12	1	18.24
01 JUN 90	27.98	9.87	19.79	16.37	0	26.38
31 MAY 90	24.86	5.553	16.67	15.37	0	30.7
30 MAY 90	20.82	6.02	13.69	14.15	0	30.79
29 MAY 90	12.86	6.392	9.737	14.8	0	28.74
28 MAY 90	23.99	7.392	16.4	15.19	0	26.98
27 MAY 90	22.6	7.872	15.8	14.04	0	29.12
26 MAY 90	19.18	11.44	14.48	14.06	0	12.5
25 MAY 90	23.63	8.262	15.72	13.67	0	24.4
24 MAY 90	19.32	10.62	14.26	13.35	3	24.59
10 MAY 90	19.04	1.706	8.915	12.54	3	8.928
09 MAY 90	19.67	8.169	14.83	13.81	9	16
08 MAY 90	29.11	7.695	19.24	12.62	0	26.62
07 MAY 90	24.65	5.938	15.35	10.79	0	27.28
06 MAY 90	16.31	6.262	9.888	10.34	0	24.42
05 MAY 90	16.84	5.58	10	9.598	6	23.27
04 MAY 90	9.747	5.539	7.154	10.67	14	1.788
03 MAY 90	17.79	2.389	10.29	11.31	0	17.78
02 MAY 90	16.29	.9447	8.156	11.8	0	27.38
01 MAY 90	14.95	6.636	10.49	13.51	0	26.7

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1991 UNIONVILLE WEATHER DATA

DATE	AIR TEMP MAX deg C	AIR TEMP MIN deg C	AIR TEMP AVG deg C	GRD TEMP deg C	RAIN mm	SOLAR MJ
06 OCT 91	6.64	1.56	4.32	7.98	.00	5.41
05 OCT 91	6.55	2.10	4.76	8.79	.00	3.21
04 OCT 91	8.91	-.87	3.72	9.55	.00	17.87
03 OCT 91	3.33	-7.21	2.56	9.76	39.00	4.21
02 OCT 91	5.54	-5.65	3.01	10.00	4.00	5.67
01 OCT 91	10.65	-3.22	6.78	10.05	.00	7.77
29 SEP 91	11.89	-2.47	5.55	11.42	.00	20.04
28 SEP 91	17.12	-3.13	5.78	11.56	.00	20.93
27 SEP 91	13.00	2.68	6.89	10.65	.00	14.40
26 SEP 91	12.50	5.65	8.29	10.01	.00	11.60
25 SEP 91	13.93	-1.51	6.34	9.01	3.00	6.10
24 SEP 91	11.26	-.42	6.29	9.66	.00	6.60
23 SEP 91	17.78	7.90	12.62	9.54	5.00	19.42
22 SEP 91	20.14	4.62	12.75	9.80	.00	9.49
21 SEP 91	18.39	1.54	10.24	11.21	.00	21.98
20 SEP 91	14.33	6.75	9.90	16.43	.00	12.96
19 SEP 91	17.83	8.00	11.31	17.65	.00	17.57
18 SEP 91	19.17	9.92	14.04	19.56	3.00	10.83
17 SEP 91	24.05	12.08	17.54	22.34	.00	22.93
16 SEP 91	27.94	17.17	22.58	25.79	4.00	14.95
15 SEP 91	32.64	19.91	25.14	24.69	.00	18.64
14 SEP 91	25.11	11.35	18.23	25.10	1.00	10.64
13 SEP 91	22.26	13.89	17.86	25.00	.00	6.62
12 SEP 91	24.47	6.20	15.54	24.58	.00	23.50
11 SEP 91	21.80	11.08	15.99	24.68	.00	19.30
10 SEP 91	25.99	15.17	21.28	25.67	3.00	16.06
09 SEP 91	31.27	19.12	23.66	25.74	.00	19.22
08 SEP 91	29.69	14.19	21.08	25.64	.00	17.51
07 SEP 91	28.23	11.84	19.47	25.39	.00	12.46
06 SEP 91	28.58	10.56	19.42	25.33	.00	25.64
05 SEP 91	28.28	6.90	17.29	24.90	.00	25.39
04 SEP 91	26.15	11.22	19.16	25.30	.00	27.50
03 SEP 91	25.58	10.12	19.09	25.12	3.00	6.68
02 SEP 91	25.22	4.35	15.70	24.63	.00	27.65
01 SEP 91	23.60	4.80	14.56	24.42	.00	28.11
31 AUG 91	23.88	9.79	18.80	25.12	.00	21.25
30 AUG 91	33.08	19.25	25.21	26.21	.00	16.76
29 AUG 91	35.52	16.80	25.39	26.36	.00	22.70
28 AUG 91	34.37	16.20	24.90	26.35	.00	25.80
27 AUG 91	33.71	16.31	24.40	26.38	.00	25.10
26 AUG 91	32.82	16.02	23.84	26.38	.00	24.17
25 AUG 91	31.06	11.93	21.09	25.81	.00	27.71

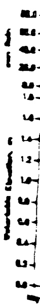
24 AUG 91	27.49	15.78	20.30	25.65	.00	24.96
23 AUG 91	23.35	12.76	18.38	25.28	.00	29.01
22 AUG 91	29.37	14.34	21.09	25.78	.00	24.22
20 AUG 91	23.60	11.18	18.42	20.50	.00	21.00
19 AUG 91	22.23	15.64	18.10	21.20	15.00	8.27
18 AUG 91	25.46	13.62	19.48	21.20	.00	15.10
17 AUG 91	24.99	15.25	20.18	22.70	.00	6.41
16 AUG 91	29.76	17.34	22.25	21.60	10.00	17.97
15 AUG 91	33.08	14.43	21.59	21.10	.00	18.75
14 AUG 91	29.78	13.18	21.11	20.50	.00	18.29
13 AUG 91	30.62	11.49	20.80	20.50	.00	23.88
12 AUG 91	28.43	9.63	19.01	20.50	.00	21.88
11 AUG 91	28.37	11.10	19.77	20.50	.00	25.88
10 AUG 91	26.84	14.33	20.12	20.50	.00	24.93
9 AUG 91	24.84	14.74	19.74	20.80	.00	24.26
8 AUG 91	19.66	12.25	16.09	21.80	.00	6.90
7 AUG 91	25.69	12.86	18.89	20.50	.00	24.39
6 AUG 91	24.13	7.04	16.11	20.50	.00	25.83
5 AUG 91	22.70	10.67	17.02	20.60	.00	26.90
4 AUG 91	23.95	12.83	18.28	21.10	.00	16.28
3 AUG 91	23.55	16.80	19.30	21.80	30.00	12.58
2 AUG 91	24.25	16.60	19.83	22.60	.00	7.07
1 AUG 91	32.44	15.79	24.26	20.50	.00	27.43
31 JUL 91	30.66	10.66	21.35	20.50	.00	26.21
30 JUL 91	26.91	15.36	20.26	20.50	.00	23.92
29 JUL 91	20.48	14.08	17.50	20.50	1.00	6.30
28 JUL 91	26.19	11.10	17.81	20.50	.00	15.88
27 JUL 91	26.30	8.62	17.84	20.50	.00	27.92
26 JUL 91	23.81	10.93	18.05	20.60	.00	28.51
25 JUL 91	25.80	15.38	19.52	20.50	.00	24.38
24 JUL 91	28.82	13.21	21.85	20.50	.00	27.69
23 JUL 91	28.03	19.43	24.23	20.50	.00	28.68
22 JUL 91	29.98	19.28	23.66	20.90	.00	13.36
21 JUL 91	27.16	20.53	23.81	23.20	10.00	8.00
20 JUL 91	35.43	19.24	27.40	20.50	.00	22.89
19 JUL 91	34.91	20.10	26.72	20.50	.00	26.14
18 JUL 91	34.29	16.97	25.86	20.50	.00	26.64
17 JUL 91	31.15	17.63	23.77	20.50	.00	21.89
16 JUL 91	30.83	13.43	22.51	20.50	.00	27.64
15 JUL 91	28.81	10.30	20.43	20.50	.00	29.63
14 JUL 91	26.12	14.08	20.78	20.50	.00	29.77
13 JUL 91	23.99	15.09	18.61	20.70	.00	18.83
12 JUL 91	22.67	10.49	16.60	20.60	.00	5.64
11 JUL 91	27.06	12.59	20.31	20.50	.00	29.65
10 JUL 91	28.86	12.98	21.18	20.50	.00	27.01
9 JUL 91	25.52	13.53	19.09	20.50	.00	28.89
8 JUL 91	26.20	14.47	21.07	21.20	.00	27.46
7 JUL 91	32.62	18.93	25.09	23.70	5.00	25.85

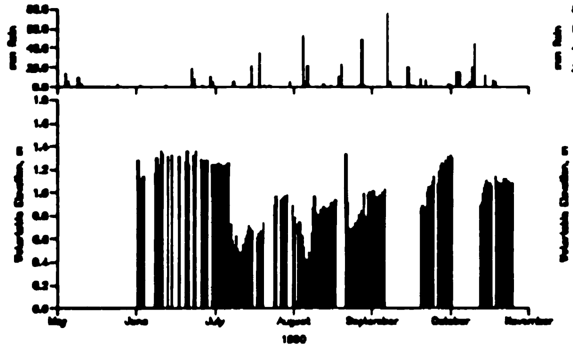
6 JUL 91	31.91	15.63	24.30	20.60	.00	24.65
5 JUL 91	28.15	16.75	22.16	21.40	.00	25.24
4 JUL 91	27.46	18.01	22.12	21.60	.00	17.40
3 JUL 91	32.78	17.14	22.70	23.20	.00	21.94
2 JUL 91	28.07	17.46	22.32	20.50	.00	25.67
1 JUL 91	28.55	12.47	20.48	20.50	.00	19.30
30 JUN 91	21.74	13.62	18.07	20.50	.00	19.85
29 JUN 91	33.15	19.43	26.10	20.50	.00	24.21
28 JUN 91	32.17	20.75	26.55	20.50	.00	26.31
27 JUN 91	32.22	21.98	26.70	22.10	.00	24.02
26 JUN 91	32.04	15.34	24.62	21.90	.00	28.05
25 JUN 91	27.79	12.21	20.83	21.20	.00	27.41
24 JUN 91	27.64	8.36	18.33	20.60	.00	30.34
23 JUN 91	24.09	11.15	17.33	20.50	.00	31.20
22 JUN 91	16.70	12.98	14.80	20.10	1.00	6.11
21 JUN 91	26.11	15.10	19.55	21.10	.00	27.52
20 JUN 91	29.83	15.74	23.62	21.90	.00	29.76
19 JUN 91	31.21	16.43	24.21	22.00	.00	29.54
18 JUN 91	28.78	14.89	22.28	21.60	.00	30.47
17 JUN 91	26.07	17.41	21.30	21.40	7.00	30.16
16 JUN 91	26.27	19.64	22.08	21.60	.00	18.74
15 JUN 91	30.31	19.10	22.84	21.70	.00	21.60
14 JUN 91	32.04	11.34	22.05	21.60	.00	27.00
13 JUN 91	23.51	7.75	16.13	20.40	.00	30.71
12 JUN 91	23.07	11.48	18.94	20.90	.00	28.29
11 JUN 91	26.00	18.46	21.31	21.40	.00	17.44
10 JUN 91	30.25	19.16	24.11	22.00	5.00	17.42
9 JUN 91	29.66	13.40	22.47	21.60	.00	28.50
8 JUN 91	29.14	12.73	20.76	21.30	.00	29.70
7 JUN 91	26.82	10.46	19.27	21.00	.00	30.32
6 JUN 91	24.26	10.00	17.63	20.30	.00	30.03
5 JUN 91	21.54	10.70	16.83	19.14	.00	30.30
4 JUN 91	18.21	10.63	14.61	20.26	.00	28.90
3 JUN 91	24.13	11.31	16.69	20.61	.00	27.28
2 JUN 91	24.20	13.99	18.54	20.72	.00	16.49
1 JUN 91	23.66	15.74	19.74	20.77	.00	26.51
31 MAY 91	28.78	19.25	22.94	20.86	.00	24.87
30 MAY 91	29.57	19.51	24.20	20.84	.00	22.72
29 MAY 91	30.34	19.45	23.74	21.13	.00	25.83
28 MAY 91	31.91	16.78	23.18	20.94	4.00	25.09
27 MAY 91	29.38	19.96	23.98	20.43	.00	27.20
26 MAY 91	27.16	17.98	22.40	19.63	.00	12.06
25 MAY 91	26.36	16.80	20.44	19.47	2.00	15.05
24 MAY 91	30.88	19.81	23.30	19.48	4.00	15.92
23 MAY 91	29.83	17.91	23.68	19.45	.00	20.02
22 MAY 91	31.24	14.26	23.06	19.40	.00	21.29
21 MAY 91	27.23	8.61	18.70	15.00	.00	25.07
20 MAY 91	20.28	4.99	13.72	13.00	.00	28.64

19 MAY 91	18.03	5.40	11.08	12.00	.00	29.90
18 MAY 91	14.50	5.06	8.71	12.00	.00	23.77
17 MAY 91	20.13	5.79	10.89	13.00	.00	4.71
16 MAY 91	31.54	14.46	23.62	19.38	2.00	23.18
15 MAY 91	28.95	12.83	21.51	19.32	.00	27.12
14 MAY 91	30.00	16.32	21.67	19.26	.00	27.27
13 MAY 91	29.86	14.87	20.91	17.99	4.00	25.45
12 MAY 91	30.58	17.62	22.74	17.69	.00	22.05
11 MAY 91	28.08	11.37	20.22	17.56	.00	24.21
10 MAY 91	21.10	8.96	15.60	10.35	.00	25.68
9 MAY 91	17.54	5.92	10.17	9.20	4.00	17.05
8 MAY 91	11.43	4.65	8.03	8.56	.00	18.47
7 MAY 91	11.93	5.51	8.06	9.12	.00	11.82
6 MAY 91	13.14	6.14	8.59	9.99	.00	3.84
5 MAY 91	17.47	1.83	9.16	7.69	6.00	14.45
4 MAY 91	11.11	2.54	5.37	6.00	.00	16.97
3 MAY 91	10.04	4.41	6.26	9.43	.00	12.29
2 MAY 91	10.25	5.81	8.05	11.50	.00	8.87
1 MAY 91	14.50	7.83	10.47	13.72	.00	9.36
					175.00	
30 APR 91	18.99	11.60	15.52	15.68	.00	19.31
29 APR 91	22.57	10.69	16.89	13.11	.00	12.95
28 APR 91	18.61	12.84	15.00	12.01	15.00	8.88
27 APR 91	23.99	9.09	16.23	10.27	9.00	18.16
26 APR 91	21.87	8.49	14.12	8.10	.00	20.17
25 APR 91	19.41	3.78	11.64	7.21	.00	23.53
24 APR 91	13.80	5.18	8.38	7.16	4.00	17.81
23 APR 91	15.51	.58	8.30	7.13	2.00	12.23
22 APR 91	15.11	4.46	8.88	7.10	.00	25.78
21 APR 91	5.64	2.02	3.47	7.02	.00	4.61
20 APR 91	3.03	1.27	2.15	7.04	.00	3.88
19 APR 91	7.84	2.45	4.84	7.09	.00	4.07
18 APR 91	12.19	.40	6.34	7.13	.00	19.41
17 APR 91	9.57	4.36	6.86	7.13	.00	19.02
16 APR 91	12.82	4.97	8.67	7.11	.00	23.54
15 APR 91	18.27	5.71	9.76	8.27	11.00	6.55
14 APR 91	9.65	2.67	6.13	7.04	4.00	3.22

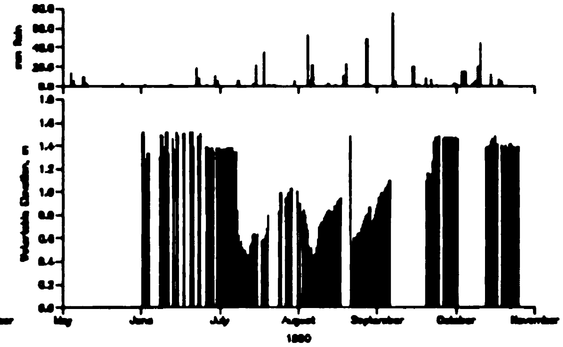
APPENDIX C

Observation Well Watertable Elevation

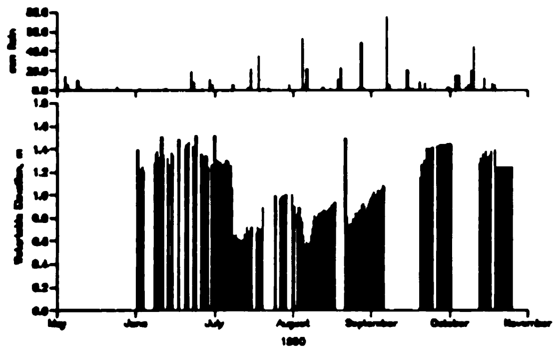




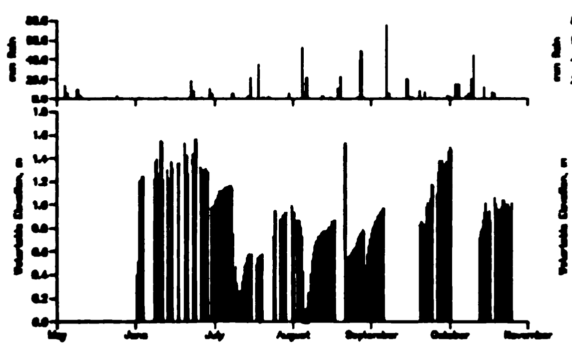
1990 SI-South: 1m from tile OWAHd1



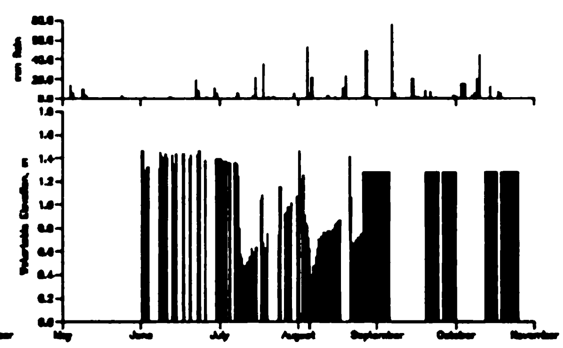
1990 SI-North: 1m from tile OWAHd4



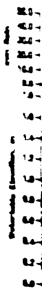
1990 SI-South: 1.65m from tile OWAHd2

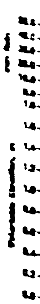


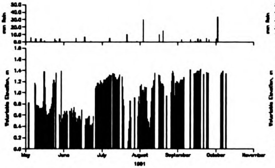
1990 SI-South: 2.3m from tile OWAHd3



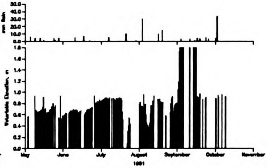
1990 SI-North: 2.3m from tile OWAHd6



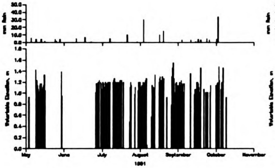




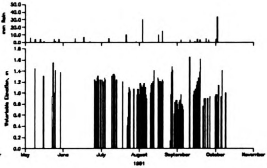
1991 SI-South: 1m from tile OWAHd1



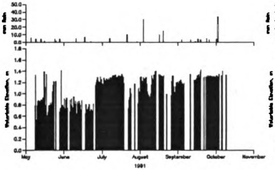
1991 SI-North: 1m from tile OWAHd4



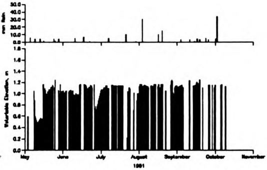
1991 SI-South: 1.65m from tile OWAHd2



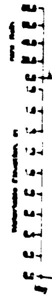
1991 SI-North: 1.65m from tile OWAHd5

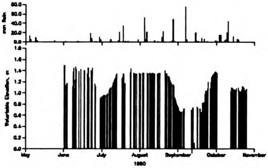


1991 SI-South: 2.3m from tile OWAHd3

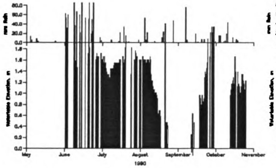


1991 SI-North: 2.3m from tile OWAHd6

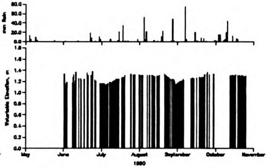




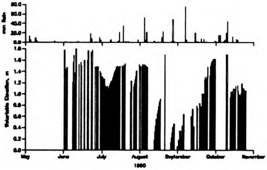
1990 DO-North: 1m from tile OWBHd4



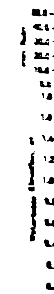
1990 DO-South: 1.65m from tile OWBHd2

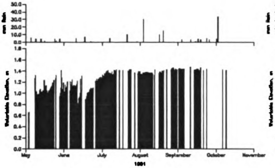


1990 DO-North: 1.65m from tile OWBHd5

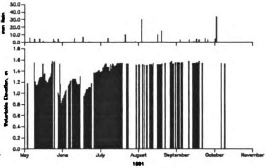


1990-South: 2.3m from tile OWBHd3

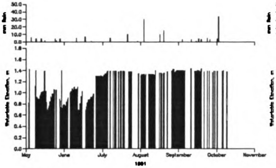




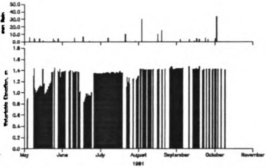
1991 DO-South: 1m from tile OWBHd1



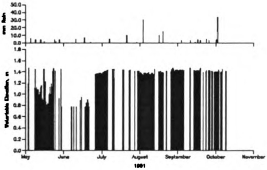
1991 DO-North: 1m from tile OWBHd4



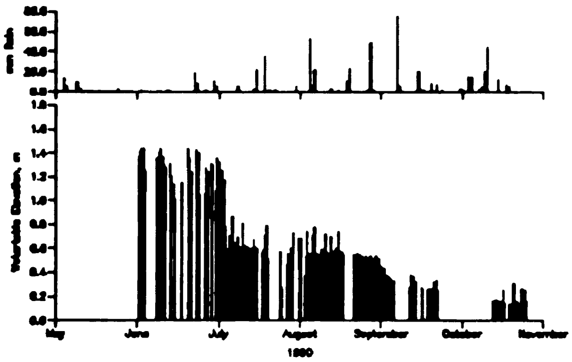
1991 DO-South: 1.65m from tile OWBHd2



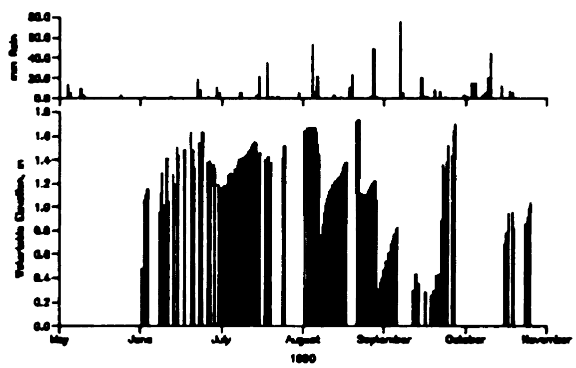
1991 DO-North: 1.65m from tile OWBHd5



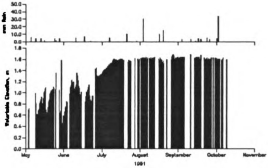
1991-South: 2.3m from tile OWBHd3



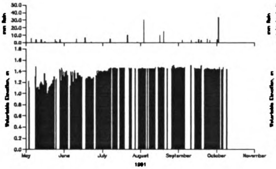
1990 ND-Southeast OWCHd1



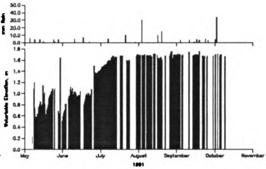
1990 ND-West OWCHd5



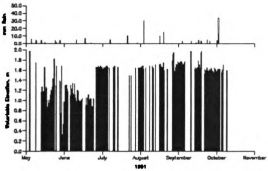
1991 ND-Southwest OWCHd4



1991 ND-East OWCHd2



1991 ND-West OWCHd5



1991 ND-Northeast OWCHd3

APPENDIX D

Water Sample Nutrient Analysis Data

UNIONVILLE WATERTABLE MANAGEMENT WATER SAMPLE NUTRIENT RESULTS
TFA# = TILE FLOW SAMPLES FROM ZONE A (SI)
TFB# = TILE FLOW SAMPLES FROM ZONE B (DO)
FA1 = SURFACE FLOW SAMPLES FROM FLUME 1 OF ZONE A
FA2 = SURFACE FLOW SAMPLES FROM FLUME 2 OF ZONE A
FB1 = SURFACE FLOW SAMPLES FROM FLUME 1 OF ZONE B
FB2 = SURFACE FLOW SAMPLES FROM FLUME 2 OF ZONE B
FC1 = SURFACE FLOW SAMPLES FROM FLUME 1 OF ZONE C
FC2 = SURFACE FLOW SAMPLES FROM FLUME 2 OF ZONE C

TMT	DATE	NO3-N	NH4-N	P	K
			ppm		
TFA	11/14/89	17.64		.07	5
TFA	11/14/89	21.05		.05	6
TFB	11/14/89	12.68		.06	6
TFB	11/14/89	15.06		.06	18
TFA	11/23/89	9.25		.07	6
TFA	11/23/89	9.86		.06	15
TFB	11/23/89	22.97		.05	6
TFB	11/23/89	19.55		.05	5
TFA	4/16/90	8.71		.09	14.7
TFA	4/16/90	8.24		.08	14.7
TFA	4/16/90	8.71		.09	14.7
TFA	4/16/90	8.24		.08	14.7
TFB	4/16/90	24.93		.07	6.3
TFB	4/16/90	23.61		.1	5.8
TFB	4/16/90	24.93		.07	6.3
TFB	4/16/90	23.61		.1	5.8
TFA	5/11/90	15.54		.1	22.6
TFA	5/11/90	11.15		.08	15.8
TFA	5/11/90	15.54		.1	22.6
TFA	5/11/90	11.15		.08	15.8
TFB	5/11/90	16.03		.07	3.7
TFB	5/11/90	15.89		.09	4.2
TFB	5/11/90	16.03		.07	3.7
TFB	5/11/90	15.89		.09	4.2
TFA	5/14/90	10.95		.09	15.3
TFA	5/14/90	9.37		.09	13.2
TFA	5/14/90	10.95		.09	15.3
TFA	5/14/90	9.37		.09	13.2
TFB	5/14/90	17.17		.08	4.2
TFB	5/14/90	15.95		.1	4.2
TFB	5/14/90	17.17		.08	4.2
TFB	5/14/90	15.95		.1	4.2
FB1	5/22/90	2.06		.04	2.6
TFA	5/24/90	9.4		.05	8.4
TFA	5/24/90	11.41		.05	9.5
TFA	5/24/90	9.4		.05	8.4

TFA
TFB
TFB
TFB
TFB
TFA
TFA
TFA
TFA
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TFB
TFB
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RAIN
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TFB
TFB
FA1
FA2
RAIN
TFA
TFA
TFA
TFA
TFB
TFB
TFB
TFB
FA1
FA2
FB1
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TFB
TFB
TFB
TFB
FA1
FA2

TFA	5/24/90	11.41	.05	9.5
TFB	5/24/90	20.8	.1	5.3
TFB	5/24/90	21.99	.09	5.3
TFB	5/24/90	20.8	.1	5.3
TFB	5/24/90	21.99	.09	5.3
TFA	6/ 1/90	14.58	.04	10
TFA	6/ 1/90	14.65	0	10
TFA	6/ 1/90	14.58	.04	10
TFA	6/ 1/90	14.65	0	10
TFB	6/ 1/90	19.41	0	4.7
TFB	6/ 1/90	22.2	.19	5.3
TFB	6/ 1/90	19.41	0	4.7
TFB	6/ 1/90	22.2	.19	5.3
RAIN	6/12/90	6.07	.19	1.1
TFA	6/19/90	17.01	.07	4.4
TFA	6/19/90	17.01	.07	4.4
TFB	6/19/90	10.41	.06	8.9
TFB	6/19/90	10.41	.06	8.9
FA1	6/25/90	20.5	.02	19.5
FA2	6/25/90	8.73	0	6.7
RAIN	6/25/90	4.13	.13	1.7
TFA	6/25/90	10.42	.03	8.9
TFA	6/25/90	10.36	.02	8.9
TFA	6/25/90	10.42	.03	8.9
TFA	6/25/90	10.36	.02	8.9
TFB	6/25/90	16.65	0	5
TFB	6/25/90	17.11	.01	5
TFB	6/25/90	16.65	0	5
TFB	6/25/90	17.11	.01	5
FA1	7/ 3/90	30.08	.1	21.4
FA2	7/ 3/90	20.94	.12	14.8
FB1	7/ 3/90	2.66	.11	6.8
TFA	7/ 3/90	9.34	.13	8.9
TFA	7/ 3/90	4.23	.11	5.3
TFA	7/ 3/90	9.34	.13	8.9
TFA	7/ 3/90	4.23	.11	5.3
TFB	7/ 3/90	10.69	0	3.3
TFB	7/ 3/90	10.69	0	3.3
TFA	7/13/90	0	.08	3.2
TFA	7/13/90	0	.08	3.2
TFA	7/13/90	0	.08	3.2
TFA	7/13/90	0	.08	3.2
TFB	7/13/90	9.75	.1	4.2
TFB	7/13/90	9.65	.1	3.7
TFB	7/13/90	9.75	.1	4.2
TFB	7/13/90	9.65	.1	3.7
FA1	7/17/90	9.25	.16	3.9
FA2	7/17/90	9.46	.16	6.1

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FB1	7/17/90	5.77	.16	5
FC1	7/17/90	4.38	.09	6.1
FC2	7/17/90	3.26	.19	9.4
RAIN	7/17/90	1.06	.21	3.2
TFA	7/17/90	.14	.1	3.2
TFA	7/17/90	.14	.1	3.2
TFB	7/17/90	7.92	.14	3.3
TFB	7/17/90	9.05	.16	3.3
TFB	7/17/90	8.19	.17	3.2
TFB	7/17/90	7.92	.14	3.3
TFB	7/17/90	9.05	.16	3.3
TFB	7/17/90	8.19	.17	3.2
TFA	7/18/90	.21	.07	3.2
TFA	7/18/90	1.48	.08	3.2
TFA	7/18/90	.44	.1	3.2
TFA	7/18/90	.21	.07	3.2
TFA	7/18/90	1.48	.08	3.2
TFA	7/18/90	.44	.1	3.2
FA1	7/19/90	4.53	.09	3.2
FB1	7/19/90	3.01	.09	4.2
FB2	7/19/90	5.52	.1	3.7
FC1	7/19/90	2.74	.09	4.2
FC2	7/19/90	1.91	.1	4.8
RAIN	7/19/90	.61	.1	3.2
TFA	7/19/90	1.34	.09	3.2
TFA	7/19/90	.22	.09	2.6
TFA	7/19/90	.32	.08	2.6
TFA	7/19/90	1.34	.09	3.2
TFA	7/19/90	.22	.09	2.6
TFA	7/19/90	.32	.08	2.6
TFB(GRAB)	7/19/90	35.94	.08	7.9
TFB(GRAB)	7/19/90	35.94	.08	7.9
FC1	7/23/90	8.55	.1	4.8
FC2	7/23/90	.48	.1	2.1
TFA(GRAB)	7/23/90	.21	.07	2.1
TFA(GRAB)	7/23/90	.21	.07	2.1
TFB	7/23/90	56.18	.09	7.4
TFB	7/23/90	51.76	.1	6.8
TFB	7/23/90	64.84	.1	8.4
TFB	7/23/90	56.18	.09	7.4
TFB	7/23/90	51.76	.1	6.8
TFB	7/23/90	64.84	.1	8.4
TFA	7/25/90	.92	.08	3.2
TFA	7/25/90	1.01	.08	3.7
TFA	7/25/90	2.41	.07	4.2
TFA	7/25/90	.92	.08	3.2
TFA	7/25/90	1.01	.08	3.7
TFA	7/25/90	2.41	.07	4.2

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TFB	7/25/90	18.89	.08	2.6
TFB	7/25/90	35.37	.08	3.7
TFB	7/25/90	35.4	.08	3.7
TFB	7/25/90	18.89	.08	2.6
TFB	7/25/90	35.37	.08	3.7
TFB	7/25/90	35.4	.08	3.7
IRRIG.	8/ 2/90	0	.1	2.6
RAIN	8/ 2/90	0	.27	1.6
TFA	8/ 2/90	3.05	.08	4.2
TFA	8/ 2/90	2.88	.07	5.3
TFA	8/ 2/90	1.93	.05	4.8
TFA	8/ 2/90	3.05	.08	4.2
TFA	8/ 2/90	2.88	.07	5.3
TFA	8/ 2/90	1.93	.05	4.8
TFB	8/ 2/90	31.05	.09	3.2
TFB	8/ 2/90	58.93	.08	6.3
TFB	8/ 2/90	58.78	.08	6.3
TFB	8/ 2/90	31.05	.09	3.2
TFB	8/ 2/90	58.93	.08	6.3
TFB	8/ 2/90	58.78	.08	6.3
FA1	8/ 6/90	8.87	.35	5.88
FB1	8/ 6/90	.74	.32	3.50
FB2	8/ 6/90	1.56	.35	2.38
FC1	8/ 6/90	.64	.35	2.38
FC2	8/ 6/90	.65	.33	2.38
RAIN	8/ 6/90	.55	.35	1.19
TFA	8/ 6/90	1.11	.01	3.2
TFA	8/ 6/90	.82	.08	3.2
TFA	8/ 6/90	.81	.35	1.19
TFA	8/ 6/90	1.11	.01	3.2
TFA	8/ 6/90	.82	.08	3.2
TFA	8/ 6/90	.81	.35	1.19
TFB	8/ 6/90	60.51	.33	5.31
TFB	8/ 6/90	43.71	.35	5.88
TFB	8/ 6/90	38.74	.33	5.31
TFB	8/ 6/90	60.51	.33	5.31
TFB	8/ 6/90	43.71	.35	5.88
TFB	8/ 6/90	38.74	.33	5.31
TFA	8/ 8/90	17.22	.35	6.50
TFA	8/ 8/90	14.07	.34	8.81
TFA	8/ 8/90	9.61	.35	10.50
TFA	8/ 8/90	17.22	.35	6.50
TFA	8/ 8/90	14.07	.34	8.81
TFA	8/ 8/90	9.61	.35	10.50
TFA	8/10/90	10.27	.34	6.50
TFA	8/10/90	10.9	.35	6.50
TFA	8/10/90	10.29	.34	10.00
TFA	8/10/90	10.27	.34	6.50

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TFA	8/10/90	10.9	.35	6.50
TFA	8/10/90	10.29	.34	10.00
TFB	8/10/90	42.04	.36	4.13
TFB	8/10/90	39.7	.33	5.31
TFB	8/10/90	34.58	.34	5.31
TFB	8/10/90	42.04	.36	4.13
TFB	8/10/90	39.7	.33	5.31
TFB	8/10/90	34.58	.34	5.31
RAIN	8/14/90	1.91	2.08	8.25
TFA	8/14/90	8.67	.36	11.56
TFA	8/14/90	9.06	.36	31.56
TFA	8/14/90	8.99	.36	27.38
TFA	8/14/90	8.67	.36	11.56
TFA	8/14/90	9.06	.36	31.56
TFA	8/14/90	8.99	.36	27.38
TFB	8/14/90	43.8	0	5.88
TFB	8/14/90	51.14	.34	7.06
TFB	8/14/90	39.47	.36	7.06
TFB	8/14/90	43.8	0	5.88
TFB	8/14/90	51.14	.34	7.06
TFB	8/14/90	39.47	.36	7.06
TFA	8/18/90	8.15	.35	27.38
TFA	8/18/90	8.56	.34	29.50
TFA	8/18/90	7.37	.35	30.00
TFA	8/18/90	8.15	.35	27.38
TFA	8/18/90	8.56	.34	29.50
TFA	8/18/90	7.37	.35	30.00
TFB	8/18/90	50.87	.02	5.88
TFB	8/18/90	48.33	.35	7.06
TFB	8/18/90	44.8	.35	4.13
TFB	8/18/90	50.87	.02	5.88
TFB	8/18/90	48.33	.35	7.06
TFB	8/18/90	44.8	.35	4.13
FA1	8/20/90	3.96	.35	5.88
FB1	8/20/90	1.22	.34	2.38
FC1	8/20/90	.55	.34	4.69
FC2	8/20/90	.42	.34	4.13
RAIN	8/20/90	.67	.31	1.69
FA1	8/28/90	1.77	.22	4.44
FB2	8/28/90	.85	.21	3.31
FC1	8/28/90	9.6	.2	5.00
FC2	8/28/90	17.82	.2	3.31
RAIN	8/28/90	.66	.22	.56
TFA	8/28/90	8.82	.18	15.81
TFA	8/28/90	8.06	.2	12.13
TFA	8/28/90	7.07	.21	13.19
TFA	8/28/90	8.82	.18	15.81
TFA	8/28/90	8.06	.2	12.13

TFA	8/28/90	7.07	.21	13.19
TFB	8/28/90	.05	1.02	12.63
TFB	8/28/90	43.85	.2	6.13
TFB	8/28/90	32.39	.2	6.69
TFB	8/28/90	.05	1.02	12.63
TFB	8/28/90	43.85	.2	6.13
TFB	8/28/90	32.39	.2	6.69
TFA	9/ 4/90	28.77	.2	12.13
TFA	9/ 4/90	9.36	.21	2.25
TFA	9/ 4/90	12.79	.19	13.19
TFA	9/ 4/90	28.77	.2	12.13
TFA	9/ 4/90	9.36	.21	2.25
TFA	9/ 4/90	12.79	.19	13.19
TFB	9/ 4/90	41.3	.15	7.25
TFB	9/ 4/90	47.6	.2	8.31
TFB	9/ 4/90	33.35	.2	7.25
TFB	9/ 4/90	41.3	.15	7.25
TFB	9/ 4/90	47.6	.2	8.31
TFB	9/ 4/90	33.35	.2	7.25
FA1	9/10/90	2.91	.23	4.44
FB1	9/10/90	1.45	.23	6.13
FB2	9/10/90	36.96	.24	12.63
FC2	9/10/90	20.64	.24	9.44
TFA	9/10/90	16.4	.2	22.63
TFA	9/10/90	16.58	.23	23.69
TFA	9/10/90	15.25	.21	24.19
TFA	9/10/90	16.4	.2	22.63
TFA	9/10/90	16.58	.23	23.69
TFA	9/10/90	15.25	.21	24.19
TFB	9/10/90	38.48	.21	5.00
TFB	9/10/90	31.4	.25	8.31
TFB	9/10/90	28.15	.23	8.31
TFB	9/10/90	38.48	.21	5.00
TFB	9/10/90	31.4	.25	8.31
TFB	9/10/90	28.15	.23	8.31
TFA	9/12/90	20.87	.18	7.25
TFA	9/12/90	21.67	.23	6.69
TFA	9/12/90	20.87	.18	7.25
TFA	9/12/90	21.67	.23	6.69
TFB	9/12/90	21.36	.22	6.69
TFB	9/12/90	69.12	.22	5.56
TFB	9/12/90	77.54	.2	8.31
TFB	9/12/90	21.36	.22	6.69
TFB	9/12/90	69.12	.22	5.56
TFB	9/12/90	77.54	.2	8.31
FA1	9/17/90	7	.24	9.44
FB1	9/17/90	6.28	.24	6.13
FC1	9/17/90	7.54	.23	12.63

FC2	9/17/90	30.85	.24	8.88
IRRIG.	9/17/90	3.5	.1	2.8
RAIN	9/17/90	.03	.22	.56
TFA	9/17/90	19.89	.25	15.81
TFA	9/17/90	31.02	.25	35.25
TFA	9/17/90	31.27	.23	39.50
TFA	9/17/90	19.89	.25	15.81
TFA	9/17/90	31.02	.25	35.25
TFA	9/17/90	31.27	.23	39.50
TFB	9/17/90	71.56	.25	8.88
TFB	9/17/90	64.36	.25	8.31
TFB	9/17/90	72.56	.24	8.31
TFB	9/17/90	71.56	.25	8.88
TFB	9/17/90	64.36	.25	8.31
TFB	9/17/90	72.56	.24	8.31
RAIN	9/19/90	1.15	1.92	2.75
TFA	9/19/90	20.2	.25	11.56
TFA	9/19/90	6.4	.27	10.00
TFA	9/19/90	19.76	.27	14.19
TFA	9/19/90	20.2	.25	11.56
TFA	9/19/90	6.4	.27	10.00
TFA	9/19/90	19.76	.27	14.19
TFB	9/19/90	48.11	.07	3.88
TFB	9/19/90	70.76	.23	7.75
TFB	9/19/90	62.57	.25	7.75
TFB	9/19/90	48.11	.07	3.88
TFB	9/19/90	70.76	.23	7.75
TFB	9/19/90	62.57	.25	7.75
FC1	9/24/90	7.4	.24	19.50
FC2	9/24/90	13.62	.24	8.31
TFA	9/25/90	18.67	.24	13.50
TFA	9/25/90	17.95	.24	7.75
TFA	9/25/90	19.36	.25	16.50
TFA	9/25/90	18.67	.24	13.50
TFA	9/25/90	17.95	.24	7.75
TFA	9/25/90	19.36	.25	16.50
TFB	9/25/90	60.5	.24	6.69
TFB	9/25/90	56.15	.24	6.13
TFB	9/25/90	55.22	.24	6.13
TFB	9/25/90	60.5	.24	6.69
TFB	9/25/90	56.15	.24	6.13
TFB	9/25/90	55.22	.24	6.13
RAIN	10/ 2/90	1.89	.37	.50
FA1	10/ 4/90	1.52	.25	12.88
FB1	10/ 4/90	1.34	.23	8.44
FB2	10/ 4/90	1.26	.23	5.81
FC1	10/ 4/90	3.04	.22	29.50
RAIN	10/ 4/90	.47	.23	2.13

TFA	10/ 4/90	17.94		.23	45.69
TFA	10/ 4/90	18.42		.23	11.44
TFA	10/ 4/90	17.94		.23	45.69
TFA	10/ 4/90	18.42		.23	11.44
FB1	10/11/90	1.3		.23	12.00
FB2	10/11/90	.65		.26	12.50
RAIN	10/11/90	.73		.23	2.63
TFA	10/11/90	38.36		.16	14.75
TFA	10/11/90	35.39		.22	13.81
TFA	10/11/90	37.38		.23	13.31
TFA	10/11/90	38.36		.16	14.75
TFA	10/11/90	35.39		.22	13.81
TFA	10/11/90	37.38		.23	13.31
TFB	10/11/90	81.26		.23	4.19
TFB	10/11/90	78.86		.25	7.38
TFB	10/11/90	58.88		.24	6.31
TFB	10/11/90	81.26		.23	4.19
TFB	10/11/90	78.86		.25	7.38
TFB	10/11/90	58.88		.24	6.31
FB1	10/18/90	.85		.21	8.6
FC1	10/18/90	1.4		.2	18.5
TFA	10/18/90	36.06		.2	13.5
TFA	10/18/90	37.64		.22	14.5
TFA	10/18/90	38.18		.21	14
TFA	10/18/90	36.06		.2	13.5
TFA	10/18/90	37.64		.22	14.5
TFA	10/18/90	38.18		.21	14
TFB	10/18/90	54.39		.21	7.1
TFB	10/18/90	52.37		.22	6.2
TFB	10/18/90	63.17		.2	7.1
TFB	10/18/90	54.39		.21	7.1
TFB	10/18/90	52.37		.22	6.2
TFB	10/18/90	63.17		.2	7.1
TFA	10/25/90	33.64		.21	20
TFA	10/25/90	33.52		.22	20
TFA	10/25/90	32.49		.22	20
TFA	10/25/90	33.64		.21	20
TFA	10/25/90	33.52		.22	20
TFA	10/25/90	32.49		.22	20
TFB	10/25/90	71.21		.23	6.7
TFB	10/25/90	61.79		.22	6.2
TFB	10/25/90	64.36		.22	6.2
TFB	10/25/90	71.21		.23	6.7
TFB	10/25/90	61.79		.22	6.2
TFB	10/25/90	64.36		.22	6.2
TFA(GRAB)	5/11/91	15.16	.07	.11	8.9375
TFB(GRAB)	5/11/91	14.89	.16	.13	2.125
FB(GRAB)	5/17/91	.99	46.37	15.61	220.5

FC1	5/17/91	1.07	2.01	n.d.	1.5625
TFA1(GRAB	5/22/91	12.88	.05	.12	11.5625
TFB14	5/22/91	15.28	.22	.1	5.25
TFB2	5/22/91	8.93	n.d.	n.d.	5.25
TFB27	5/22/91	14.22	n.d.	.12	4.75
TFA1	5/24/91	9.97	n.d.	.12	10.5
TFA2	5/24/91	15.98	.14	.11	15.25
TFB1	5/24/91	4.27	.03	.07	2.125
TFB5	5/24/91	10.03	.05	.12	2.125
TFB7	5/24/91	8.18	n.d.	.11	2.125
FA1	5/27/91	.55	.76	.16	.5
FA2	5/27/91	.21	.42	.1	.5
FB1	5/27/91	.93	.74	.15	2.125
FB2	5/27/91	.54	.47	.12	1.5625
FC1	5/27/91	.73	.61	.14	2.625
FC2	5/27/91	.85	.49	.11	2.625
TFB12	5/27/91	8.19	.04	.12	2.625
TFB2	5/27/91	5.94	n.d.	.1	2.125
TFB23	5/27/91	15.4	.15	.12	3.6875
FA1	5/29/91	11.35	.61	.26	10
FA2	5/29/91	21.11	.31	.24	16.3125
FB1	5/29/91	24.09	.37	.19	12.125
FB2	5/29/91	30.24	.23	.15	18.4375
FC1	5/29/91	24.06	.29	.11	20.5
FC2	5/29/91	31.33	.34	.12	21.5
TFA1	5/29/91	15.26	.3	.08	15.8125
TFA2	5/29/91	31.55	.3	.11	6.3125
TFA3	5/29/91	22.56	.15	.11	4.75
TFB14	5/29/91	38.32	n.d.	.11	3.6875
TFB2	5/29/91	46.68	n.d.	.1	5.8125
TFB27	5/29/91	40.87	.13	.11	3.1875
TFA13	6/ 6/91	20.44	.05	.11	18.9375
TFA2	6/ 6/91	7.77	.18	.12	1.0625
TFA24	6/ 6/91	20.12	.03	.12	26
TFB14	6/ 6/91	31.83	.06	.09	3.6875
TFB2	6/ 6/91	34.33	.12	.12	4.1875
TFB27	6/ 6/91	17.57	.07	.12	2.625
TFA1	6/ 8/91	12.59	.15	.12	12.125
TFA2	6/ 8/91	16.33	.15	.09	25
TFA3	6/ 8/91	17.93	n.d.	.12	22
TFB2	6/ 8/91	24.21	.05	.12	4.75
TFB4	6/ 8/91	22.31	.05	.11	3.6875
TFB6	6/ 8/91	28.89	.04	.11	4.1875
TFA1	6/10/91	18.94	.05	.12	23.875
TFA2	6/10/91	11.89	n.d.	.12	17.875
TFA3	6/10/91	14.25	n.d.	.12	20.5625
TFB13	6/10/91	10.48	.02	.12	2.25
TFB2	6/10/91	24.12	.03	.12	5.5625

TFB7	6/10/91	15.46	.05	.12	3.3125
FB2	6/17/91	.25	.69	.13	8.875
FC1	6/17/91	.75	.5	.11	10
FC2	6/17/91	.91	.27	.12	10
TFA11	6/17/91	22.56	.3	.11	38.625
TFA2	6/17/91	21.51	.9	.1	33.625
TFA20	6/17/91	21.52	.15	.11	35.4375
TFB10	6/17/91	22.91	.08	.11	5.5625
TFB2	6/17/91	17	.18	.1	4.4375
TFB6	6/17/91	21	.09	.11	3.875
TFA2	6/20/91	22.6	.12	.12	34.5625
TFA3	6/20/91	22.41	.06	.11	34.5625
TFA4	6/20/91	22.28	.07	.1	27.25
TFB14	6/20/91	24.91	.46	.11	6.6875
TFB2	6/20/91	20.18	n.d.	.11	6.6875
TFB27	6/20/91	27.89	.7	.1	4.4375
TFA2	6/25/91	22.47	.11	.11	29.4375
TFA4	6/25/91	19.93	.62	.11	17.375
TFA5	6/25/91	23.45	.13	.11	30.9375
TFB14	6/25/91	27.77	.41	.11	5.5625
TFB2	6/25/91	16.32	.09	.11	4.4375
TFB27	6/25/91	22.12	.59	.11	3.875
TFA1	6/27/91	20.97	.29	.11	28.3125
TFA2	6/27/91	22.42	.1	.11	28.875
TFA3	6/27/91	22.9	.09	.11	31.375
TFB10	6/27/91	28.16	.97	.1	6.125
TFB19	6/27/91	33.22	.59	.09	4.4375
TFB2	6/27/91	23.69	.94	.1	5
TFA2	7/ 2/91	23.2	.22	.11	25
TFA6	7/ 2/91	25.93	.15	.11	26.125
TFA9	7/ 2/91	23.48	.22	.1	27.25
TFB14	7/ 2/91	29.8	.06	.09	5.5625
TFB2	7/ 2/91	25.86	.04	.09	5
TFB27	7/ 2/91	22.17	.09	.1	6.125
LAE2	7/ 9/91	22.55	n.d.	.04	28.875
LAE3	7/ 9/91	27.12	.01	.11	6.125
LAN3	7/ 9/91	27.38	.04	.11	5
LAS2	7/ 9/91	2.33	.54	.1	2.25
LAS3	7/ 9/91	1.76	.85	.77	1.6875
LAW2	7/ 9/91	27.3	.06	.11	5
LAW3	7/ 9/91	28.63	.11	.11	5
LBE3	7/ 9/91	33.51	.03	.1	3.1875
LBN3	7/ 9/91	1.89	.97	.11	1.5625
TFA2	7/ 9/91	22.53	.04	.11	25.25
TFA3	7/ 9/91	22.76	.11	.1	26.8125
TFA4	7/ 9/91	n.d.	.09	.11	12.125
TFA1	7/10/91	.32	.25	.11	3.1875
TFA2	7/10/91	n.d.	.24	.11	2.625

TFB2	7/10/91	18.76	n.d.	.11	4.75
TFB5	7/10/91	19.25	.19	.13	5.25
TFB8	7/10/91	19.88	.04	.11	5.8125
Irr. H2O	7/18/91	n.d.	.18	.11	2.125
TFA2	7/18/91	.19	.33	.11	2.125
TFA3	7/18/91	.16	.23	.11	2.625
TFA4	7/18/91	.15	.26	.11	2.625
TFB15	7/18/91	26.19	.18	.1	4.75
TFB2	7/18/91	26.54	.2	.11	4.1875
TFB9	7/18/91	23.74	.02	.11	3.1875
FA1	7/24/91	.9	.16	.1	1.5625
FA2	7/24/91	1	.14	.11	2.125
FB1	7/24/91	.89	.2	.1	1.5625
FB2	7/24/91	1.1	.13	.13	1.5625
FC1	7/24/91	.64	.18	.1	1.0625
Irrig.	7/24/91	.33	.09	.12	2.125
TFA2	7/25/91	n.d.	.55	.13	2.625
TFA4	7/25/91	n.d.	.51	.11	2.625
TFB12	7/25/91	empty	empty	.1	VIAL EMPTY
TFB2	7/25/91	19.52	n.d.	.1	4.1875
TFB5	7/25/91	n.d.	.43	.11	2.625
TFB7	7/25/91	23.25	.32	.11	4.75
RAIN	7/29/91	1.75	1.13	.27	2.625
TFA2	7/29/91	n.d.	.45	.11	2.625
TFA3	7/29/91	n.d.	.49	.11	2.625
TFA4	7/29/91	n.d.	.36	.11	2.625
FA1	8/10/91	1.63	.56	.11	22.625
FA2	8/10/91	1.03	.65	.11	1.5625
FB1	8/10/91	1.57	.66	.11	1.0625
FB2	8/10/91	1.11	.57	.1	1.0625
FC1	8/10/91	1.08	.49	.11	1.0625
FC2	8/10/91	1.27	.56	.11	1.0625
TFA1	8/10/91	.1	.28	.11	2.125
TFA2	8/10/91	.06	.37	.11	2.625
TFA2	8/15/91	.52	.25	.12	4.1875
TFA3	8/15/91	.65	.2	.11	3.1875
TFA4	8/15/91	.63	.29	.11	2.625
TFB13	8/15/91	15.08	.34	.11	5.8125
TFB2	8/15/91	15.16	.44	.1	3.1875
TFB25	8/15/91	14.38	.24	.12	5.8125
RAIN	8/16/91				
FA1	8/19/91	.51	.28	.11	.5
FA2	8/19/91	.55	.27	.12	.5
FB1	8/19/91	.36	.35	.1	1.0625
FB2	8/19/91	.6	.41	.11	.5
FC1	8/19/91	n.d.	.47	.12	4.1875
FC2	8/19/91	n.d.	.34	.13	4.75
RAIN	8/19/91	.3	.71	.13	.5

TFA2	8/19/91	.72	.24	.1	3.1875
TFA5	8/19/91	1.29	.26	.11	4.75
TFA7	8/19/91	1.38	.22	.11	3.6875
TFB15	8/19/91	13.92	.25	.1	4.1875
TFB2	8/19/91	14.81	.27	.11	5.25
TFB27	8/19/91	12.93	.22	.1	4.75
TFA2	8/27/91	.85	.22	.1	3.1
TFA6	8/27/91	.91	.22	.14	4.2
TFA9	8/27/91	1.01	.19	.11	4.2
TFB2	8/28/91	5.94	.3	.16	4.1875
TFB5	8/28/91	5.88	.66	.24	4.1875
TFB8	8/28/91	5.65	.22	.72	3.1875
FC1	9/ 4/91	n.d.	.33	.06	3.1875
FC2	9/ 4/91	.14	.32	.14	3.6875
TFA12	9/ 4/91	.4	.21	.15	4.1875
TFA2	9/ 4/91	.16	.21	.15	4.1875
TFA7	9/ 4/91	.13	.19	.16	4.1875
TFA14	9/ 6/91	.65	.19	.14	4.75
TFA2	9/ 6/91	.49	.21	.15	4.1875
TFA27	9/ 6/91	.66	.24	.15	2.625
LAS3	9/12/91	.52	.3	.15	4.75
TFA15	9/12/91	.49	.25	.15	3.1875
TFA2	9/12/91	.86	.23	.15	3.6875
TFA8	9/12/91	.36	.2	.15	3.1875
TFB14	9/12/91	8.02	.67	.15	6.3125
TFB2	9/12/91	8.55	.49	.16	5.8125
TFB7	9/12/91	6.62	.39	.15	5.8125
TFA1	9/20/91	.47	.21	.12	4.75
TFA2	9/20/91	.48	.26	.15	3.1875
TFB1	9/20/91	4.47	.55	.18	5.8125
FB2	10/ 5/91	1.08	.5	.16	1.5625
FC1	10/ 5/91	.95	.45	.16	1.0625
FC2	10/ 5/91	.62	.34	.15	1.0625
TFA1	10/ 5/91	.88	.48	.15	1.0625
TFB2	10/ 5/91	.65	.25	.14	1.5625
FA1	10/22/91	.96	.71	.07	.5
FA2	10/22/91	2	.56	.15	.5
FB1	10/22/91	1.28	.81	.15	.5
FB2	10/22/91	1.4	.72	.14	.5
FC1	10/22/91	1.17	.54	.15	2.125
FC2	10/22/91	1.13	.59	.13	1.0625

APPENDIX E

Soil Sample Nutrient Analysis Data

WATER MANAGEMENT PROJECT UNIONVILLE- SOIL DATA
A = SI Treatment
B = DO Treatment
C = ND Treatment

TMT	DEPTH/ REP	DATE COLLECT.	NO3 in ppm	NH4-N ppm	P lb/ac	K lb/ac
A	1S	9/14/89	9.6		78	84
A	2S	9/14/89	1.67		2	67
A	3S	9/14/89	6.61		3	76
A	1N	9/14/89	15.89		133	118
A	2N	9/14/89	3.9		46	303
A	3N	9/14/89	5.27		3	93
B	1S	9/14/89	8.4		69	216
B	2S	9/14/89	12.47		6	93
B	3S	9/14/89	5.61		3	109
B	1N	9/14/89	8.41		3	101
B	2N	9/14/89	7.1		1	76
B	3N	9/14/89	3.66		3	93
C	1E	9/14/89	6.79		36	240
C	2E	9/14/89	3.25		22	135
C	3E	9/14/89	2.26		29	109
C	1W	9/14/89	3.9		69	101
C	2W	9/14/89	2.86		14	93
C	3W	9/14/89	3.84		1	109
A	1S	4/16/90	5.87		138	177
A	2S	4/16/90	2.03		7	107
A	3S	4/16/90	1.75		1	107
A	1N	4/16/90	4.79		107	168
A	2N	4/16/90	1.05		2	71
A	3N	4/16/90	1.18		1	71
B	1S	4/16/90	16.97		143	236
B	2S	4/16/90	6.39		1	80
B	3S	4/16/90	4.04		1	80
B	1N	4/16/90	42.37		84	219
B	2N	4/16/90	24.52		2	89
B	3N	4/16/90	13.4		1	89
C	1E	4/16/90	6.98		11	124
C	2E	4/16/90	3.62		1	107
C	3E	4/16/90	2.38		2	98
C	1W	4/16/90	9.59		41	219
C	2W	4/16/90	1.32		1	98
C	3W	4/16/90	.84		1	107
A	1S	5/14/90	32.14		169	269

A	2S	5/14/90	3.62	2	80
A	3S	5/14/90	4.39	1	89
A	1N	5/14/90	55.04	156	320
A	2N	5/14/90	1.85	3	80
A	3N	5/14/90	2.22	1	80
B	1S	5/14/90	56.44	147	354
B	2S	5/14/90	6.96	2	133
B	3S	5/14/90	6.19	2	133
B	1N	5/14/90	70.83	78	503
B	2N	5/14/90	14.71	2	98
B	3N	5/14/90	7.82	1	116
C	1E	5/14/90	50.57	6	168
C	2E	5/14/90	7.58	1	116
C	3E	5/14/90	7.29	1	133
C	1W	5/14/90	18.81	94	177
C	2W	5/14/90	3.21	18	62
C	3W	5/14/90	3.31	2	80
A	1S	5/24/90	82.93	186	424
A	2S	5/24/90	1.34	5	109
A	3S	5/24/90	2.32	1	126
A	1N	5/24/90	66.02	148	295
A	2N	5/24/90	.71	2	76
A	3N	5/24/90	.57	18	84
B	1S	5/24/90	62.28	154	344
B	2S	5/24/90	1.57	1	84
B	3S	5/24/90	1.33	7	93
B	1N	5/24/90	73.63	87	269
B	2N	5/24/90	18.93	3	84
B	3N	5/24/90	11.89	1	84
C	1E	5/24/90	70.12	18	253
C	2E	5/24/90	14.75	36	135
C	3E	5/24/90	6.14	1	118
C	1W	5/24/90	31.05	107	177
C	2W	5/24/90	3.33	5	67
C	3W	5/24/90	6.85	3	59
A	1S	6/ 7/90	10.02	173	261
A	2S	6/ 7/90	.68	5	98
A	3S	6/ 7/90	.94	1	107
A	1N	6/ 7/90	7.46	186	320
A	2N	6/ 7/90	.22	2	71
A	3N	6/ 7/90	.15	1	71
B	1S	6/ 7/90	11.86	200	344
B	2S	6/ 7/90	.85	1	71
B	3S	6/ 7/90	.57	1	89
B	1N	6/ 7/90	15.28	98	261
B	2N	6/ 7/90	2.68	1	80
B	3N	6/ 7/90	1.42	1	89
C	1E	6/ 7/90	3.8	95	133

C	2E	6/ 7/90	.51	1	53
C	3E	6/ 7/90	.88	5	71
C	1W	6/ 7/90	8.46	31	202
C	2W	6/ 7/90	1.24	2	116
C	3W	6/ 7/90	.65	1	107
A	1S	6/19/90	5.59	155	227
A	2S	6/19/90	1.55	4	107
A	3S	6/19/90	1.59	1	107
A	1N	6/19/90	5.33	160	244
A	2N	6/19/90	2.31	3	80
A	3N	6/19/90	2.29	1	80
B	1S	6/19/90	6.72	186	312
B	2S	6/19/90	1.7	5	89
B	3S	6/19/90	2.38	1	107
B	1N	6/19/90	12.06	95	253
B	2N	6/19/90	4.62	4	89
B	3N	6/19/90	2.92	2	89
C	1E	6/19/90	4.31	101	116
C	2E	6/19/90	1.25	2	71
C	3E	6/19/90	1.34	1	80
C	1W	6/19/90	10.42	29	211
C	2W	6/19/90	2.4	1	116
C	3W	6/19/90	5.2	1	124
A	1S	7/ 3/90	71.52	200	286
A	2S	7/ 3/90	10.58	3	122
A	3S	7/ 3/90	3.11	3	104
A	1N	7/ 3/90	42.18	174	219
A	2N	7/ 3/90	2.11	3	66
A	3N	7/ 3/90	1.38	1	75
B	1S	7/ 3/90	57.69	182	336
B	2S	7/ 3/90	13.7	1	94
B	3S	7/ 3/90	9.33	1	113
B	1N	7/ 3/90	133.58	90	320
B	2N	7/ 3/90	26.27	1	94
B	3N	7/ 3/90	11.36	1	94
C	1E	7/ 3/90	39.21	113	286
C	2E	7/ 3/90	4.49	1	66
C	3E	7/ 3/90	7.14	2	66
C	1W	7/ 3/90	42.42	8	269
C	2W	7/ 3/90	6.84	1	122
C	3W	7/ 3/90	9.32	2	122
A	1S	8/ 8/90	44.17	168	185
A	2S	8/ 8/90	4.66	1	93
A	3S	8/ 8/90	3.43	1	93
A	1N	8/ 8/90	39.4	150	177
A	2N	8/ 8/90	2.08	1	152
A	3N	8/ 8/90	2.53	1	152
B	1S	8/ 8/90	59.67	199	392

B	2S	8/ 8/90	5.21		1	93
B	3S	8/ 8/90	4.45		1	101
B	1N	8/ 8/90	95.34		59	278
B	2N	8/ 8/90	18.54		1	67
B	3N	8/ 8/90	8.74		1	84
C	1E	8/ 8/90	30.81		114	152
C	2E	8/ 8/90	4.33		1	59
C	3E	8/ 8/90	4.24		1	59
C	1W	8/ 8/90	119.03		39	194
C	2W	8/ 8/90	6.07		1	101
C	3W	8/ 8/90	2.84		1	93
A	1S	9/12/90	26.5		112	165
A	2S	9/12/90	3.75		1	87
A	3S	9/12/90	4.55		1	32
A	1N	9/12/90	25.35		132	132
A	2N	9/12/90	4.85		1	15
A	3N	9/12/90	2.3		1	23
B	1S	9/12/90	23.75		176	233
B	2S	9/12/90	7.35		1	86
B	3S	9/12/90	4.25		1	32
B	1N	9/12/90	118.85		56	244
B	2N	9/12/90	24.85		1	52
B	3N	9/12/90	8.7		1	61
C	1E	9/12/90	9.4		96	123
C	2E	9/12/90	2.65		1	44
C	3E	9/12/90	3.6		1	12
C	1W	9/12/90	67.4		23	170
C	2W	9/12/90	17.15		1	76
C	3W	9/12/90	4.25		1	48
A	1S	11/15/90	9.4		7.6	143
A	2S	11/15/90	7.2		7.6	6
A	3S	11/15/90	4.45		7.7	1
A	1N	11/15/90	7.65		7.7	160
A	2N	11/15/90	9.2		7.7	9
A	3N	11/15/90	10		7.9	1
B	1S	11/15/90	8.2		8	136
B	2S	11/15/90	9.6		8	32
B	3S	11/15/90	5.2		7.6	1
B	1N	11/15/90	21.4		7.7	15
B	2N	11/15/90	28.75		7.8	1
B	3N	11/15/90	21.8		7.8	1
A	1E	5/11/91	17.21	3.87	69	91
A	1E	5/22/91	23.35	4.7	91	98
A	1E	6/ 6/91	25.36	5.75	136	194
A	1E	6/25/91	18.6	8.7	150	133
A	1E	7/ 9/91	7.15	6	140	142
A	1E	8/15/91	.34	5.1	68	126
A	1N	5/11/91	3.1	7.95	138	143

A	1N	5/22/91	6.32	4.56	68	100
A	1N	6/ 6/91	10.35	5.1	97	103
A	1N	6/25/91	24.68	6.42	198	219
A	1N	7/ 9/91	26.55	10.85	200	232
A	1N	8/15/91	7.25	3.7	37	107
A	1S	5/11/91	8.23	3.91	67	105
A	1S	5/22/91	12.4	4.55	87	117
A	1S	6/ 6/91	22.73	4.93	120	177
A	1S	6/25/91	20.75	8	41	176
A	1S	7/ 9/91	14.65	4	174	176
A	1S	8/15/91	15.35	7.6	74	160
A	1W	5/11/91	12.21	3.8	96	112
A	1W	5/22/91	14.85	3.4	101	121
A	1W	6/ 6/91	34.07	6.76	120	168
A	1W	6/25/91	17.95	10.6	55	133
A	1W	7/ 9/91	8.95	7.45	136	176
A	1W	8/15/91	4.25	20.95	60	126
A	2E	5/11/91	4.32	4.1	13	82
A	2E	5/22/91	13.2	3.2	12	83
A	2E	6/ 6/91	4.57	4.72	15	84
A	2E	6/25/91	5.2	8.8	15	89
A	2E	7/ 9/91	2.65	5.1	18	71
A	2E	8/15/91	4.55	6.7	26	101
A	2N	5/11/91	4.38	3.4	13	61
A	2N	5/22/91	5.6	2.4	14	72
A	2N	6/ 6/91	4.46	5.35	22	84
A	2N	6/25/91	8.35	8.65	44	107
A	2N	7/ 9/91	7.25	4	44	116
A	2N	8/15/91	2.7	7.1	37	101
A	2S	5/11/91	2.3	2.98	4	71
A	2S	5/22/91	2.2	3.25	5	82
A	2S	6/ 6/91	8.36	4.93	20	118
A	2S	6/25/91	5.55	8.65	28	98
A	2S	7/ 9/91	4.65	6.8	20	80
A	2S	8/15/91	.27	6.2	20	118
A	2W	5/11/91	3.1	3.03	4	81
A	2W	5/22/91	2.8	2.55	5	92
A	2W	6/ 6/91	3.56	6.19	11	84
A	2W	6/25/91	4	8.25	35	80
A	2W	7/ 9/91	4.35	2.25	24	109
A	2W	8/15/91	1.65	15.65	30	93
A	3E	5/11/91	3.12	4.1	3	82
A	3E	5/22/91	3.2	3.7	5	82
A	3E	6/ 6/91	3.47	5.47	2	84
A	3E	6/25/91	5.1	8.55	1	80
A	3E	7/ 9/91	3.15	6.45	2	71
A	3E	8/15/91	1.8	6.15	1	109
A	3N	5/11/91	3.98	4.75	1	80

A	3N	5/22/91	4.2	3.15	2	96
A	3N	6/ 6/91	3.19	5.74	1	76
A	3N	6/25/91	5.85	8.5	2	98
A	3N	7/ 9/91	10.15	4.15	150	184
A	3N	8/15/91	1.7	7.1	2	109
A	3S	5/11/91	3.01	3.7	2	68
A	3S	5/22/91	2.65	2.6	3	85
A	3S	6/ 6/91	4.31	4.66	1	118
A	3S	6/25/91	7	7.75	2	116
A	3S	7/ 9/91	3.05	8.35	2	71
A	3S	8/15/91	3.28	6.7	2	118
A	3W	5/11/91	4.05	3.91	1	86
A	3W	5/22/91	4.65	3.5	1	96
A	3W	6/ 6/91	4.94	4.48	1	84
A	3W	6/25/91	3.85	9.95	1	89
A	3W	7/ 9/91	5.45	2.85	3	109
A	3W	8/15/91	1.55	14.85	1	109
B	1E	5/11/91	9.96	4.01	72	86
B	1E	5/22/91	10.25	4.05	85	99
B	1E	6/ 6/91	13.4	5.33	211	278
B	1E	6/25/91	5.9	8.1	24	133
B	1E	7/ 9/91	18.75	3.05	70	208
B	1E	8/15/91	4.1	6.6	24	168
B	1N	5/11/91	2.8	2.2	5	76
B	1N	5/22/91	3.5	2.9	4	96
B	1N	6/ 6/91	6.9	3.66	10	109
B	1N	6/25/91	5.05	8.4	13	107
B	1N	7/ 9/91	4.3	2.7	22	118
B	1N	8/15/91	1.95	5.55	30	232
B	1S	5/11/91	4.92	2.41	6	82
B	1S	5/22/91	3.95	3	7	94
B	1S	6/ 6/91	7.27	4.86	18	109
B	1S	6/25/91	7.05	10.9	1	116
B	1S	7/ 9/91	4.55	2.65	1	101
B	1S	8/15/91	1.65	5.95	9	184
B	1W	5/11/91	10.92	3.01	61	103
B	1W	5/22/91	11.5	3.1	72	106
B	1W	6/ 6/91	34.63	5.04	189	236
B	1W	6/25/91	14.25	6.8	44	133
B	1W	7/ 9/91	177.8	4.05	150	560
B	1W	8/15/91	3.2	14.3	32	118
B	2E	5/11/91	4.8	4.32	10	81
B	2E	5/22/91	5.1	2.55	13	91
B	2E	6/ 6/91	10.83	3.79	11	93
B	2E	6/25/91	8.9	7.9	11	107
B	2E	7/ 9/91	7.55	2.15	11	109
B	2E	8/15/91	1.8	8.6	15	109
B	2N	5/11/91	8.92	3.68	1	91

B	2N	5/22/91	11.5	3.95	1	94
B	2N	6/ 6/91	7.52	5.21	2	93
B	2N	6/25/91	14.8	10.05	1	124
B	2N	7/ 9/91	10.9	2.45	1	109
B	2N	8/15/91	1.05	8.15	1	118
B	2S	5/11/91	11.34	3.21	98	102
B	2S	5/22/91	16.2	3.35	95	109
B	2S	6/ 6/91	11.07	4.46	189	202
B	2S	6/25/91	10.6	8.4	24	116
B	2S	7/ 9/91	13.85	3.75	160	200
B	2S	8/15/91	4.95	9.6	37	126
B	2W	5/11/91	2.21	2.06	5	72
B	2W	5/22/91	2.65	3.15	7	87
B	2W	6/ 6/91	4.92	5.01	11	101
B	2W	6/25/91	7.55	8.15	18	89
B	2W	7/ 9/91	4.45	2.7	24	84
B	2W	8/15/91	1.45	8.15	10	84
B	3E	5/11/91	6.01	3.21	1	64
B	3E	5/22/91	5.85	4.55	3	62
B	3E	6/ 6/91	2.62	6.56	2	101
B	3E	6/25/91	5.5	9.25	1	89
B	3E	7/ 9/91	3.6	2.55	7	59
B	3E	8/15/91	1.3	7.3	2	152
B	3N	5/11/91	21.02	12.21	71	103
B	3N	5/22/91	28.35	17.65	83	121
B	3N	6/ 6/91	28.47	5.98	163	303
B	3N	6/25/91	7.1	6.3	18	98
B	3N	7/ 9/91	9.85	3.5	64	143
B	3N	8/15/91	3.85	5.2	8	126
B	3S	5/11/91	1.31	5.32	4	82
B	3S	5/22/91	2.55	4.35	12	86
B	3S	6/ 6/91	7.83	4.73	8	84
B	3S	6/25/91	5.7	6.2	10	89
B	3S	7/ 9/91	5.3	2.85	53	101
B	3S	8/15/91	1.3	5.45	6	132
B	3W	5/11/91	4.23	5.1	3	96
B	3W	5/22/91	5.75	4.4	4	92
B	3W	6/ 6/91	4.94	4.69	10	101
B	3W	6/25/91	9.9	6.35	1	98
B	3W	7/ 9/91	3.4	3.75	3	84
B	3W	8/15/91	4.65	6.4	1	143
C	1E	5/11/91	11.21	2.5	36	91
C	1E	5/22/91	17	6.35	71	102
C	1E	6/ 6/91	12.95	8.65	83	261
C	1E	6/25/91	13.75	3.5	56	124
C	1E	7/ 9/91	14.95	4.05	37	84
C	1E	8/15/91	27.85	9.95	80	84
C	1N	5/11/91	3.98	2.1	3	71

C	1N	5/22/91	6.55	2.4	4	86
C	1N	6/ 6/91	4.07	5.01	11	109
C	1N	6/25/91	11.25	3.7	18	62
C	1N	7/ 9/91	2.65	2.15	24	59
C	1N	8/15/91	21.55	6.4	10	67
C	1S	5/11/91	2.32	1.87	2	68
C	1S	5/22/91	6.35	3.35	5	82
C	1S	6/ 6/91	1.58	5.64	2	76
C	1S	6/25/91	8.75	5.1	1	98
C	1S	7/ 9/91	2.45	2.3	2	59
C	1S	5/11/91	9.11	4.98	50	91
C	1W	5/22/91	12.15	5.8	62	114
C	1W	6/ 6/91	9.35	6.42	99	93
C	1W	6/25/91	2.65	4.15	13	80
C	1W	7/ 9/91	7.05	3	41	101
C	1W	8/15/91	2.3	5.65	28	93
C	1W	5/11/91	1.02	3.21	11	81
C	2E	5/22/91	4.5	2.35	17	78
C	2E	6/ 6/91	.74	5.12	11	84
C	2E	6/25/91	2.45	4.55	10	80
C	2E	7/ 9/91	1.15	2	13	76
C	2E	8/15/91	1.5	5.3	8	59
C	2N	5/11/91	2.57	2.02	3	61
C	2N	5/22/91	7.15	2.95	11	82
C	2N	6/ 6/91	2.36	4.14	5	59
C	2N	6/25/91	3.15	4.5	1	98
C	2N	7/ 9/91	1.15	3.1	1	84
C	2S	5/11/91	8.76	4.32	71	100
C	2S	5/22/91	16.8	9.15	82	109
C	2S	6/ 6/91	13.65	5.24	96	160
C	2S	6/25/91	3.8	3.8	11	98
C	2S	7/ 9/91	10.55	2.45	53	160
C	2S	8/15/91	3.4	4.9	82	84
C	2W	5/11/91	1.65	3.45	5	81
C	2W	5/22/91	1.85	5.55	7	90
C	2W	6/ 6/91	3.51	3.85	10	84
C	2W	6/25/91	4.4	5.15	10	98
C	2W	7/ 9/91	2.8	2.85	22	76
C	2W	8/15/91	18.9	4.9	13	67
C	3E	5/11/91	.98	2.32	1	76
C	3E	5/22/91	1.95	3.05	1	89
C	3E	6/ 6/91	1.07	4.51	4	84
C	3E	6/25/91	4	4.65	1	107
C	3E	7/ 9/91	3.2	3.35	3	93
C	3N	5/11/91	12.1	4.6	62	101
C	3N	5/22/91	14.6	4.7	90	114
C	3N	6/ 6/91	23.25	5.3	108	126
C	3N	6/25/91	16.8	5.8	58	200

C	3N	7/ 9/91	2.01	.67	39	236
C	3N	8/15/91	1.8	5.8	43	101
C	3S	5/11/91	5.43	3.01	9	82
C	3S	5/22/91	9.45	3	12	96
C	3S	6/ 6/91	4.11	4.42	10	84
C	3S	6/25/91	2.75	8.75	11	107
C	3S	7/ 9/91	.28	.51	10	152
C	3S	8/15/91	1.7	6.05	10	51
C	3W	5/11/91	2.98	4.32	3	87
C	3W	5/22/91	9.6	3.4	1	91
C	3W	6/ 6/91	3.86	5.35	2	93
C	3W	6/25/91	1.75	4.35	3	107
C	3W	7/ 9/91	.14	.61	2	118

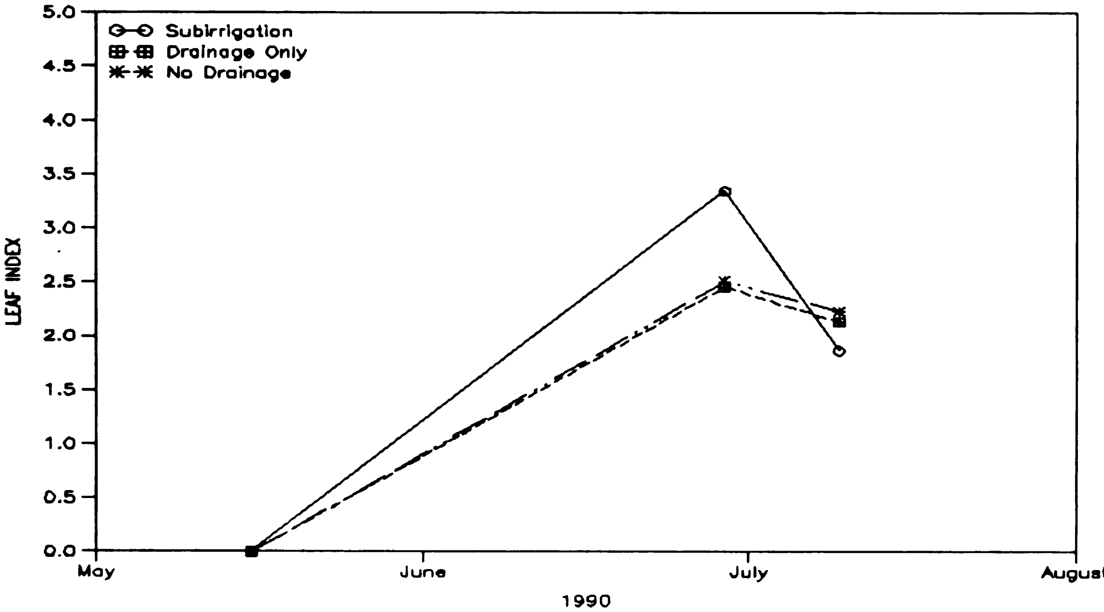
APPENDIX F

Soil Alachlor Analysis Data

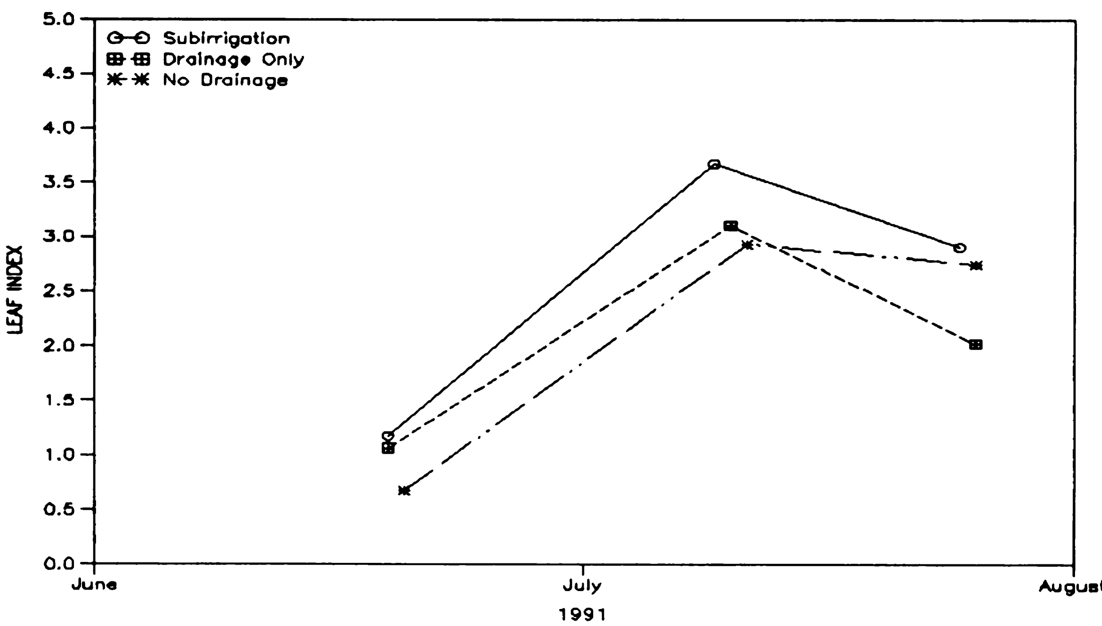
Soil Sample Location	Date	Alachlor, ppb
SI-North, 0-0.3m	6/7/91	<0.05
SI-North, 0-0.3m	6/25/91	<0.05
SI-South, 0-0.3m	6/7/91	<0.05
SI-South, 0-0.3m	6/25/91	<0.05
DO-North, 0-0.3m	6/7/91	<0.05
DO-North, 0-0.3m	6/25/91	<0.05
DO-South, 0-0.3m	6/7/91	<0.05
DO-South, 0-0.3m	6/25/91	<0.05
ND-North, 0-0.3m	6/7/91	<0.05
ND-North, 0-0.3m	6/25/91	<0.05
ND-South, 0-0.3m	6/7/91	<0.05
ND-South, 0-0.3m	6/25/91	<0.05

APPENDIX G

Crop Yield, Leaf Area, Stem Volume and Plant Biomass Nutrient Analysis Data



1990 Leaf Index



1991 Leaf Index

CORN YIELD DATA - UNIONVILLE - 1990 GROWING SEASON
A = SI   B = DO   C = ND
DATE PLANTED: 5/ 8/90
DATE OF HARVEST: 11/ 8/90

LOCATION CODE	MOIST WGT lb	MOIST CONTENT %	PLOT SIZE ft*ft	PLOT SIZE m*m	YIELD m**3/ha *10	YIELD bu/ac	YIELD mtons/ha	TRT YIELD bu
AS	26846	23.8	125692	11681	135.0	155	2.32	447.3
AN	29253	24.32	125692.0	11681	146.4	168	2.52	485.2
BS	22907	25.18	106128.0	9863	134.8	155	2.32	377.3
BN	20006	24.53	102131.0	9492	123.0	141	2.12	331.2
C	25200	15.50	141345.6	13136	120.7	139	2.08	449.9
TOTALS	26846		125692.0	11681		155		447

AVERAGE YIELD: 149 bu/ac   2.24mtons/ha

ZONE A: 161.57 bu/ac   2.42mtons/ha

ZONE B: 148.07 bu/ac   2.22mtons/ha

ZONE C: 138.64 bu/ac   2.08mtons/ha

	EMERGED POPUL plt/ha
ZONE A:	65000.00
ZONE B:	66500.00
ZONE C:	67000.00

CORN YIELD DATA - UNIONVILLE - 1991 GROWING SEASON
A = SI   B = DO   C = ND
DATE PLANTED: 5/16/91
DATE OF HARVEST: 10/ 8/91

LOCATION CODE	MOIST WGT lb	MOIST CONTENT %	PLOT SIZE ft*ft	PLOT SIZE m*m	YIELD m**3/ha *10	YIELD bu/ac	YIELD mtons/ha	TRT YIELD bu
AS	14740	23.3	55577	5163	168.3	193	2.90	246.6
AN	15829	19.43	59186.4	5499	175.2	201	3.02	273.4
BS	11434	15.20	72888.2	6772	106.5	122	1.84	204.7
BN	11007	14.70	67619.2	6282	111.0	128	1.91	197.9
CS	11547	14.83	79685.0	7403	98.7	113	1.70	207.4
CN	11614	14.83	82175.2	7634	96.3	111	1.66	208.6
TOTALS	14740		55577.4	5163		193		247

AVERAGE YIELD: 145 bu/ac 2.17mtons/ha

ZONE A: 197.23 bu/ac 2.96mtons/ha

ZONE B: 124.93 bu/ac 1.87mtons/ha

ZONE C: 111.98 bu/ac 1.68mtons/ha

	EMERGED POPUL plt/ha
ZONE A:	66300.00
ZONE B:	66700.00
ZONE C:	65800.00

Unionville Plant Measurements 1990

DATE	SI Leaf Area Index m^2/m^2	DO Leaf Area Index m^2/m^2	ND Leaf Area Index m^2/m^2
7/18/90	2.883855	2.60015	2.394044
7/18/90	4.39712	2.578338	3.014732
7/18/90	4.10423	2.124808	3.158112
7/18/90	3.78209	2.306486	3.091916
7/18/90	3.62674	2.605071	2.850716
7/18/90	3.34919	2.781296	2.081288
7/18/90	3.177265	1.422302	2.937012
7/18/90	3.3111	2.689061	1.6549
7/18/90	6.418815	2.84354	2.176428
7/18/90	3.288415	3.445897	2.597724
7/18/90	3.616925	2.663192	1.463548
7/18/90	4.43898	3.133746	2.401816
7/18/90	3.438825	2.157726	1.467032
7/18/90	4.06653	3.649786	2.416824
7/18/90	2.901925	2.018408	1.693224
7/18/90	2.75717	2.31553	2.149628
7/18/90	3.377075	1.384796	2.328116
7/18/90	3.655145	1.611162	2.914768
7/18/90	3.76324	1.762782	1.985076
7/18/90	3.18214	1.471512	2.15204
7/18/90	3.89415	3.010588	3.09406
7/18/90	3.18955	2.327101	1.126672
7/18/90	2.477865	2.488962	2.962472
7/18/90	3.170505	1.846639	2.715376
7/18/90	2.200185	2.110245	2.551092
7/18/90	2.604355	2.743258	1.975696
7/18/90	2.66331	2.206071	1.837408
7/18/90	2.67631	2.724372	3.223504
7/19/90	3.05422	2.005906	2.329456
7/19/90	2.87157	1.762516	2.443356
7/19/90	2.50237	3.207162	3.596761
7/19/90	3.37363	1.98037	3.218144
7/19/90	3.1252	2.70123	3.126622
7/19/90	2.78889	2.790606	3.156772
7/19/90	3.16199	2.475396	2.718056
7/18/90	5.01202	2.579668	2.52121
7/18/90	3.497715	3.045900	2.124101
7/18/90	3.7427	2.048998	2.207918
7/18/90	2.80033	3.221792	3.619943
7/18/90	3.5256	2.61744	2.441212

7/18/90	3.37129	2.808229	2.42808
7/18/90	3.382665	2.654148	2.718056
7/18/90	4.580485	2.395596	2.714974
7/18/90	4.357275	2.468148	2.508413
7/18/90	3.761485	2.857572	2.617824
7/18/90	3.727035	2.644506	1.954524
7/18/90	3.155529	2.824455	3.076104
7/18/90	3.367455	2.808229	2.295956
7/18/90	3.809728	2.539635	2.40664
7/18/90	3.434301	1.90855	2.454076
7/18/90	3.36284	1.735916	2.871352
7/18/90	3.507244	2.232006	2.809176
7/18/90	3.11415	2.385488	2.362152
7/18/90	3.573635	2.240518	2.731188
7/18/90	3.89168	2.35144	2.345
7/18/90	3.014284	2.285472	2.273444
7/18/90	3.855085	2.104991	2.334816
7/18/90	3.17187	2.865286	2.687504
7/18/90	2.73403	2.774779	2.66794
7/18/90	2.86143	3.14944	2.37448
7/18/90	2.73962	1.628585	2.87832
7/18/90	2.58336	2.618238	2.14266
7/18/90	3.211	2.623691	2.230028
7/18/90	3.35673	2.3807	2.459436
7/18/90	2.56854	2.637124	2.373676
7/18/90	2.70894	2.748578	1.972212
7/18/90	2.760615	2.019206	2.182324
7/18/90	2.840435	2.286669	2.962204
7/18/90	3.430245	2.600948	2.877248
7/18/90	2.22703	3.040314	3.088097
8/2/90	2.24224	1.892856	2.360544
8/2/90	2.579005	2.735544	2.3785
8/2/90	2.42086	1.893122	1.870908
8/2/90	1.69182	1.898176	1.927724
8/2/90	1.36656	2.239188	1.914324
8/2/90	1.80804	1.645742	2.500976
8/2/90	1.81142	1.621004	1.826956
8/2/90	2.62132	2.335214	2.439604
8/2/90	2.23652	2.110178	1.869836
8/2/90	1.43858	2.293984	2.991148
8/2/90	2.29164	2.00298	1.575304
8/2/90	1.73264	2.424324	2.340712
8/2/90	1.48616	2.265788	1.457652
8/2/90	2.07532	2.518089	2.150164
8/2/90	2.10054	2.413152	2.0904
8/2/90	2.59012	2.380966	2.134888
8/2/90	1.38606	1.581636	2.309892
8/2/90	2.40448	1.880886	2.319808

8/2/90	2.30334	1.76092	2.291668
8/2/90	2.00174	1.557696	2.203094
8/2/90	1.77346	1.672076	1.706624
8/2/90	2.18634	2.25701	1.300872
8/2/90	2.46402	2.07347	2.09308
8/2/90	2.18296	2.19184	1.69376
8/2/90	2.0046	2.135448	2.279608
8/2/90	2.30204	2.240784	2.03412
8/2/90	1.89306	1.919722	2.123096
8/2/90	2.00694	2.183594	2.597188
8/2/90	2.2373	2.467682	2.551092
8/2/90	1.75422	2.095282	1.843304
8/2/90	2.06076	2.446934	2.263528
8/2/90	2.07974	2.289728	2.451932
8/2/90	1.47602	2.215514	2.26326
8/2/90	2.32492	2.96856	2.568244
8/2/90	1.68038	2.345854	2.021792
8/2/90	1.70248	2.292654	2.514376
8/2/90	1.45366	2.187052	2.354112
8/2/90	1.46094	1.935948	2.334548
8/2/90	1.44196	1.98303	2.82472
8/2/90	2.1684	1.76757	2.473372
8/2/90	1.31768	2.251956	2.567708
8/2/90	1.00672	1.870778	2.217164
8/2/90	1.80856	2.459104	1.676072
8/2/90	1.37228	1.346226	6.543488
8/2/90	2.65382	2.248232	2.220916
8/2/90	2.01188	2.435762	1.860188
8/2/90	1.25944	2.171624	2.610052
8/2/90	1.49058	1.868118	2.338032
8/2/90	2.14344	2.281216	2.419236
8/2/90	2.06492	2.043146	1.977036
8/2/90	1.74304	2.092888	1.876
8/2/90	1.95364	2.214184	2.17482
8/2/90	1.5405	2.09076	2.585731
8/2/90	1.41752	2.582594	2.383592
8/2/90	1.74746	1.912806	2.223864
8/2/90	1.44443	1.89924	2.016432
8/2/90	1.37852	1.84072	2.007588
8/2/90	1.20848	2.230144	1.692956
8/2/90	1.71314	1.960686	2.3182
8/2/90	2.08962	2.121084	2.358668
8/2/90	2.05244	1.89126	2.276124
8/2/90	1.73082	2.12268	1.891812
8/2/90	1.07458	2.532054	1.87198
8/2/90	1.69936	2.679418	2.13328
8/2/90	1.75162	1.954302	2.263528
8/2/90	1.6978	2.463958	2.003568

8/2/90	1.80024	2.37937	1.9564
8/2/90	1.75604	1.568868	2.351164
8/2/90	2.04646	2.51902	2.223328
8/2/90	1.8603	2.101134	2.137568

Unionville Plant Measurements 1991

DATE	SI Leaf Area Index m^2/m^2	DO Leaf Area Index m^2/m^2	ND Leaf Area Index m^2/m^2
6/19/91	1.170328	1.089665	.6219416
6/19/91	.8939892	1.361801	.738276
6/19/91	1.222572	1.302411	.8301328
6/19/91	1.210108	1.156311	.977788
6/19/91	1.440301	1.339496	1.105703
6/19/91	1.204008	1.092172	1.203087
6/19/91	1.170593	1.033797	.9841048
6/19/91	.9518028	1.019229	.600096
6/19/91	.84864	.9920158	.4121712
6/19/91	1.061330	.6470434	.8677704
6/19/91	1.012799	.7566982	.7440664
6/19/91	1.026589	1.000713	.5127136
6/19/91	.8465184	1.037585	.55272
6/19/91	1.023407	.8641652	.67116
6/19/91	1.081751	.7213738	.3482136
6/19/91	1.210638	1.070828	.2963632
6/19/91	1.058678	.8114989	.5898312
6/19/91	.9886656	.8182756	.6535256
6/19/91	1.141686	.996498	.86198
6/19/91	1.267656	.955144	.992264
6/19/91	1.045684	.969818	.3990112
6/19/91	1.464700	.9736599	.7651224
6/19/91	1.699455	1.092012	.626416
6/19/91	1.641588	1.189341	.55272
6/19/91	1.596769	1.284589	.718536
6/19/91	1.727778	1.313777	.7964432
6/19/91	1.533386	1.075044	1.056748
6/19/91	1.712662	1.008771	.7324856
6/19/91	1.759072	1.060263	.7035336
6/19/91	1.472390	1.029901	.8677704
6/19/91	1.104823	.6589426	.9972648
6/19/91	1.497054	1.101991	.8232896
6/19/91	1.423328	1.024886	.6959008
6/19/91	5.582725	1.057008	.9385712
6/19/91	1.332015	1.026540	1.075172
6/19/91	1.183057	1.015067	.4061176
6/19/91	1.030832	.7214272	.6164144
6/19/91	1.202152	.8738234	.7043232
6/19/91	1.102702	1.078512	.4537568

6/19/91	1.246970	1.116398	.9512048
6/19/91	.975936	1.185552	.5063968
6/19/91	.9780576	.9613871	.7485408
6/19/91	.6123468	.9082939	.806708
6/19/91	.9748752	1.075151	.6822144
6/19/91	.7635108	1.278132	.8564528
6/19/91	.8259654	.4997698	1.107546
6/19/91	.9157356	1.171519	1.133602
6/19/91	.6584916	.8518390	1.132550
6/19/91	.937482	.9841185	1.029902
6/19/91	.1819272	1.181390	.7085344
6/19/91	1.037728	.8799064	.7311696
6/19/91	1.056689	1.056795	.6624744
6/19/91	.6608784	1.397072	.5379808
6/19/91	1.471064	1.345899	.6674752
6/19/91	1.370288	1.359506	.7530152
6/19/91	1.225224	1.087850	.8375024
6/19/91	1.353316	1.210365	.3483189
6/19/91	1.003252	1.506780	.2942050
6/19/91	.8687952	1.189501	.1108598
6/19/91	1.393891	.8681672	.3516352
6/19/91	1.154681	1.340563	.143444
6/19/91	.9512724	1.084435	.2376696
6/19/91	1.032689	.9793694	.6322064
6/19/91	.8733036	1.244195	.380324
6/19/91	.9022104	1.222958	.4021696
6/19/91	.3338868	.9662962	.318472
6/19/91	.9555156	1.408117	.2021376
6/19/91	.9655932	1.168317	.4176984
6/19/91	.851292	.8997563	.4376490
6/19/91	.7746492	1.439279	.6569998
7/ 9/91	3.641196	3.441453	3.426338
7/ 9/91	3.797664	3.568984	3.505561
7/ 9/91	4.844408	3.486809	3.572150
7/ 9/91	4.685819	3.8686	3.434497
7/ 9/91	4.727720	3.136501	4.065124
7/ 9/91	4.718704	3.034316	4.774448
7/ 9/91	4.989473	2.890511	3.523458
7/ 9/91	3.961292	3.075670	2.708854
7/ 9/91	4.434409	2.916924	3.234202
7/ 9/91	4.365192	3.310721	3.527406
7/ 9/91	4.365457	3.491878	3.248151
7/ 9/91	4.433083	3.322194	2.371695
7/ 9/91	3.109735	3.241086	3.259206
7/ 9/91	3.930264	3.175720	2.669374
7/ 9/91	2.17464	3.237084	2.680692
7/ 9/91	3.864494	3.495347	1.404962
7/ 9/91	4.109274	3.004435	2.986794

7/	9/91	2.890150	2.887843	3.722964
7/	9/91	4.577882	2.656528	3.229464
7/	9/91	4.377656	2.934266	3.259995
7/	9/91	4.347954	3.201333	2.332794
7/	9/91	4.193077	2.891578	2.220355
7/	9/91	4.047217	2.937735	2.487766
7/	9/91	4.410011	3.330998	2.308264
7/	9/91	4.499383	3.042320	2.077701
7/	9/91	3.986486	3.265899	2.657267
7/	9/91	3.808802	2.967616	2.859142
7/	9/91	4.054643	2.719226	3.151030
7/	9/91	3.654986	3.082874	3.515299
7/	9/91	2.739516	2.757378	3.470029
7/	9/91	2.715648	2.761113	4.192250
7/	9/91	3.841952	2.684008	2.760178
7/	9/91	4.075594	2.981223	2.728594
7/	9/91	4.000542	3.551642	3.233938
7/	9/91	3.500110	3.135700	3.703224
7/	9/91	3.528751	3.225879	3.346904
7/	9/91	2.966792	3.007903	2.615682
7/	9/91	3.287419	3.484408	2.662479
7/	9/91	3.474650	3.169851	1.656054
7/	9/91	4.012476	2.805669	3.349852
7/	9/91	3.059612	2.809404	2.044538
7/	9/91	3.545989	2.654126	2.293525
7/	9/91	2.963080	3.227746	2.896779
7/	9/91	2.651204	2.785659	3.221831
7/	9/91	3.501170	2.584758	3.463975
7/	9/91	3.094884	3.319792	3.400018
7/	9/91	3.211837	2.644788	3.682168
7/	9/91	2.767892	3.178122	3.961950
7/	9/91	3.356106	3.140236	3.699013
7/	9/91	3.144211	3.337935	4.438342
7/	9/91	2.735273	3.279506	3.334744
7/	9/91	3.556067	2.973219	3.225779
7/	9/91	3.531668	3.145305	3.735071
7/	9/91	3.382626	3.693579	4.141715
7/	9/91	3.194599	3.091945	4.0138
7/	9/91	2.878746	3.085595	3.869303
7/	9/91	3.259573	3.113823	2.010848
7/	9/91	3.473590	3.095947	1.739489
7/	9/91	2.932847	3.212539	1.635525
7/	9/91	3.389256	3.398765	2.364062
7/	9/91	3.887036	3.315524	1.082805
7/	9/91	3.12273	3.284575	1.549458
7/	9/91	3.481015	2.984958	3.169981
7/	9/91	3.779896	2.758712	1.581306
7/	9/91	3.972166	2.762180	2.016112

7/ 9/91	3.349476	3.165048	2.035326
7/ 9/91	3.584974	3.012972	1.643158
7/ 9/91	3.543337	2.518592	2.100336
7/ 9/91	4.456156	3.443588	2.0069
7/ 9/91	3.505944		3.232359
7/24/91	2.713739	2.173033	3.131448
7/24/91	2.416715	2.076238	3.574203
7/24/91	3.259944	2.148754	2.883567
7/24/91	2.809953	1.653093	2.632421
7/24/91	.5306652	2.046783	2.289524
7/24/91	2.614554	2.107560	2.609207
7/24/91	2.693636	2.171912	2.253413
7/24/91	3.516393	2.614160	2.885883
7/24/91	3.373185	2.355204	3.539145
7/24/91	3.688720	2.976528	2.670532
7/24/91	3.011452	2.212359	2.679113
7/24/91	3.347301	2.071649	1.950207
7/24/91	2.921390	2.266199	2.513823
7/24/91	2.851696	2.851772	2.596994
7/24/91	2.499669	2.365502	3.106708
7/24/91	2.871373	2.798839	2.026587
7/24/91	2.596308	2.613039	2.416387
7/24/91	2.411411	2.256861	3.356748
7/24/91	2.339435	1.884195	2.123340
7/24/91	2.456813	2.311342	2.753809
7/24/91	2.228051	2.311022	2.714171
7/24/91	2.846657	1.641994	2.459393
7/24/91	3.096953	1.900416	2.616366
7/24/91	3.577124	1.785746	2.666532
7/24/91	4.259483	2.161454	2.176769
7/24/91	2.741585	2.068821	2.738649
7/24/91	3.209610	2.174633	2.320634
7/24/91	2.628662	1.948014	2.688641
7/24/91	3.395674	2.411765	3.031748
7/24/91	2.367122	2.174367	3.400018
7/24/91	3.489183	2.189094	3.469344
7/24/91	2.996548	2.296134	2.838033
7/24/91	3.520795	2.695907	2.743492
7/24/91	3.348468	2.569337	2.246149
7/24/91	2.929187	2.075651	2.890094
7/24/91	2.893014	2.383271	3.979426
7/24/91	3.172535	1.900256	3.053436
7/24/91	2.889248	2.355097	2.924310
7/24/91	2.609409	1.635110	2.544091
7/24/91	2.465458	1.685642	3.070965
7/24/91	3.263551	1.618942	2.733964
7/24/91	2.941386	2.001960	2.537669
7/24/91	2.410403	2.299603	2.289314

7/24/91	3.183249	1.555657	2.790394
7/24/91	2.749541	2.438232	3.063964
7/24/91	2.796375	1.851966	2.372327
7/24/91	3.109894	2.028534	2.746439
7/24/91	3.182877	1.829181	2.360799
7/24/91	2.604794	1.466173	2.914993
7/24/91	3.182294	2.307073	3.492453
7/24/91	2.798762	2.468380	2.858089
7/24/91	2.980689	1.678385	2.730805
7/24/91	2.417192	1.039026	3.766181
7/24/91	2.756277	1.302358	3.730807
7/24/91	3.065500	1.570758	3.405282
7/24/91	2.933589	1.847216	2.881882
7/24/91	2.655129	1.617608	2.453603
7/24/91	3.420868	2.188934	2.613365
7/24/91	2.929505	1.751062	2.678481
7/24/91	3.245942	1.818402	2.769338
7/24/91	2.516271	1.527003	1.354322
7/24/91	3.035850	1.777635	2.493662
7/24/91	2.831965	.9116022	2.858510
7/24/91	2.939212	1.830622	2.461288
7/24/91	2.745403	2.084615	2.533984
7/24/91	2.810218	1.663605	2.783024
7/24/91	2.835731	1.558165	2.448234
7/24/91	3.402092	1.625506	2.384697
7/24/91	2.505397	1.547814	2.569253
7/24/91	3.491676		2.628736

Unionville Kernel Biomass
A = SI B = DO C = ND

PLANT ID	DATE	BIOMASS (G)	Kg/ha
AN	8/8/90	145	9425
AS	8/8/90	143.5	9327.5
BN	8/8/90	121.7	8093.05
BS	8/8/90	128.2	8525.3
CE	8/8/90	130.9	8770.3
CW	8/8/90	128.9	8636.3
AN1	9/4/91	155.1	10283.13
AN2	9/4/91	189.9	12590.37
AN3	9/4/91	135.4	8977.02
AN4	9/4/91	162.9	10800.27
AN5	9/4/91	175.9	11662.17
AN6	9/4/91	147.1	9752.73
AN7	9/4/91	155.5	10309.65
AN8	9/4/91	151.8	10064.34
AN9	9/4/91	151.3	10031.19
AN10	9/4/91	135.8	9003.54
AS1	9/4/91	157.5	10442.25
AS2	9/4/91	156.7	10389.21
AS3	9/4/91	168.6	11178.18
AS4	9/4/91	176.6	11708.58
AS5	9/4/91	149.6	9918.48
AS6	9/4/91	163.1	10813.53
AS7	9/4/91	102	6762.6
AS8	9/4/91	268.7	17814.81
AS9	9/4/91	321.8	21335.34
AS10	9/4/91	181.9	12059.97
BN1	9/4/91	35.9	2394.53
BN2	9/4/91	134.6	8977.82
BN3	9/4/91	75.8	5055.86
BN4	9/4/91	126	8404.2
BN5	9/4/91	109	7270.3
BN6	9/4/91	111.9	7463.73
BN7	9/4/91	102.5	6836.75
BN8	9/4/91	128	8537.6
BN9	9/4/91	106.2	7083.54
BN10	9/4/91	141.8	9458.06
BS1	9/4/91	127.3	8490.91
BS2	9/4/91	125.3	8357.51
BS3	9/4/91	108.4	7230.28
BS4	9/4/91	126	8404.2
BS5	9/4/91	108	7203.6
BS6	9/4/91	126.4	8430.88

BS7	9/4/91	98.1	6543.27
BS8	9/4/91	147.3	9824.91
BS9	9/4/91	109.5	7303.65
BS10	9/4/91	119.3	7957.31
CN1	9/4/91	177	11646.6
CN2	9/4/91	113.9	7494.62
CN3	9/4/91	42.8	2816.24
CN4	9/4/91	116.5	7665.7
CN5	9/4/91	151.7	9981.86
CN6	9/4/91	61.5	4046.7
CN7	9/4/91	136	8948.8
CN8	9/4/91	118.7	7810.46
CN9	9/4/91	127.3	8376.34
CN10	9/4/91	93.1	6125.98
CS1	9/4/91	97.4	6408.92
CS2	9/4/91	137.6	9054.08
CS3	9/4/91	146.3	9626.54
CS4	9/4/91	2.9	190.82
CS5	9/4/91	71.5	4704.7
CS6	9/4/91	147.3	9692.34
CS7	9/4/91	155.3	10218.74
CS8	9/4/91	0	0
CS9	9/4/91	97.2	6395.76
CS10	9/4/91	130	8554

Unionville Watertable Management Project 1990

		Biomass	
7/18/90		g/m^2	
REP	SI	DO	ND
1	500.91	460.4960	437.574
2	593.6163	402.5316	579.0948
3	584.4025	288.5488	533.719
4	782.6688	306.3378	511.676
5	898.6938	471.4311	421.3935
6	688.37	486.1574	353.2713
7	556.6475	151.7936	532.5465
8	531.7363	421.1497	286.087
9	697.925	370.6809	290.1908
10	727.8413	714.8814	466.4175
11	625.6938	508.4844	176.5755
12	619.8925	420.0192	424.3248
13	810.8788	234.4556	117.4815
14	532.76	536.3932	503.9375
15	525.3663	313.4269	220.5443
16	256.2338	369.1233	317.979
17	734.6663	190.3017	511.5588
18	653.5625	191.8959	551.7755
19	866.8438	275.5650	268.9685
20	480.5488	155.3484	432.0633
21	740.695	692.1433	450.4715
22	512.74	422.0038	110.5638
23	315.0425	369.7171	630.333
24	586.6775	230.6621	486.9363
25	345.3	421.1497	519.18
26	327.1	357.8502	341.1945
27	461.4388	234.4556	314.9305
28	562.2213	346.8786	554.0033
29	486.35	342.3748	274.831
30	506.4838	230.6889	222.8893
31	346.665	616.0491	647.3343
32	746.155	542.8976	476.8528
33	669.0325	469.9255	427.9595
34	489.7625	332.2190	395.4813
35	532.76	386.2614	411.5445
36	662.5783	480.9644	346.9398
37	674.6508	335.4956	258.2988
38	761.6609	224.1248	227.3448
39	390.7123	531.122	339.6703
40	608.2520	387.0498	203.8948
41	640.3888	511.3383	263.8095
42	695.3491	443.2589	415.4138
43	646.8626	428.8284	320.793

44	656.0510	578.9521	252.788
45	438.0983	615.0284	345.7673
46	734.5312	313.5008	257.8298
47	677.6511	438.1384	440.388
48	404.9123	555.0953	390.5568
49	575.4901	301.2814	332.6353
50	471.7754	428.712	292.653
51	630.0129	245.6541	522.1113
52	630.0129	404.8551	341.0773
53	572.0947	466.883	308.8335
54	707.1739	419.9839	332.6353
55	890.6346	569.9913	258.2988
56	625.6554	437.091	395.4813
57	512.7836	288.8293	310.475
58	660.5112	428.3629	384.9288
59	562.2568	303.027	354.092
60	579.2226	601.9944	268.9685
61	373.7912	174.3163	333.6905
62	316.4758	307.3329	309.1853
63	499.2958	396.3598	352.216
64	675.8206	331.1898	396.771
65	663.2793	420.333	343.774
66	544.3847	528.6781	227.462
67	517.6099	325.2546	290.1908
68	523.2086	648.0789	418.6968
69	518.4962	597.3394	501.827
70	313.1609	334.1505	310.5804

8/ 2/90 g/m^2

REP	SI	DO	ND
1	1134.839	996.622	1157.372
2	1536.149	911.7846	1406.059
3	1276.003	810.8875	1354
4	1484.165	805.6506	1237.454
5	1817.68	1020.595	1213.066
6	1398.17	1117.652	943.2733
7	952.3838	442.5606	1133.687
8	1456.41	875.9411	890.5108
9	1454.704	917.8361	849.9423
10	1248.134	1270.569	1034.025
11	1112.999	925.2841	411.31
12	1328.214	980.6786	1246.951
13	1187.278	639.6999	376.2523
14	1258.599	1352.264	1368.305
15	1078.533	1014.195	697.7518
16	791.0863	1095.657	893.2075
17	1284.306	598.5031	1329.378

18	1422.058	706.6155	1135.681
19	1565.269	861.5106	814.5328
20	1302.393	530.4238	1188.560
21	1304.554	1444.549	1170.387
22	1308.649	910.6209	293.0048
23	844.0938	949.4901	1205.679
24	1398.739	577.4393	984.6625
25	745.3588	972.7651	1081.159
26	911.775	842.076	902.0013
27	1159.864	684.737	746.0588
28	1258.599	992.898	1379.561
29	1142.688	950.8866	1008.816
30	1274.865	521.2301	705.4903
31	920.7613	1283.952	1362.911
32	1405.678	1005.816	1251.524
33	1284.079	1413.71	907.8638
34	1274.41	1289.072	1066.620
35	1148.261	1175.258	809.3738
36	1398.136	1159.547	38.455
37	1265.262	892.35	875.8545
38	1233.909	648.5444	651.6725
39	902.5352	1168.857	1166.048
40	1503.547	962.175	519.7663
41	1137.085	1026.298	905.5188
42	1079.080	980.0968	1203.686
43	1515.307	1061.908	777.599
44	1398.136	1089.257	717.9188
45	1181.732	1228.325	975.048
46	1246.950	897.936	740.6653
47	1053.372	891.5354	1203.686
48	1131.504	1085.533	1093.705
49	1290.345	844.2871	1146.585
50	1198.475	1115.325	768.688
51	1315.427	729.425	1140.136
52	1320.530	1175.258	1210.603
53	1129.520	1271.849	871.1645
54	1310.820	1145.000	1063.924
55	1399.002	1334.226	794.6003
56	1004.725	1109.389	910.4433
57	1226.379	723.7226	846.073
58	1164.990	1100.196	928.7343
59	1098.258	992.0834	732.106
60	1145.599	1303.619	761.7703
61	906.1717	741.4116	1085.615
62	819.7353	801.4611	621.7738
63	1092.438	965.7826	826.7268
64	1404.645	1083.671	1221.977
65	1385.117	1064.701	833.0583

66	1103.600	1518.680	578.0395
67	1233.909	1124.635	719.5603
68	1027.683	1373.793	1007.761
69	1270.175	1412.779	1477.113
70	1016.967	1494.940	1140.136

Unionville Watertable Management Project 1991

6/19/91 REP	SI	Biomass g/m^2 DO	ND
1	328.0275	336.2624	306.4617
2	312.6173	345.0667	304.8982
3	335.7026	345.7261	306.5094
4	328.7285	332.2364	313.6545
5	316.0008	328.0560	321.1686
6	326.6985	325.7496	332.6569
7	338.8155	333.2684	333.0526
8	316.3456	328.0808	306.9809
9	317.4132	330.8356	299.7492
10	310.6447	312.5616	323.2567
11	321.0082	317.2938	317.5452
12	331.9656	328.6367	303.6490
13	316.3118	334.3538	306.2028
14	324.5017	331.0358	308.2710
15	326.5736	315.5676	296.1711
16	341.0974	313.6704	296.5068
17	324.4762	304.7430	305.7643
18	320.9801	310.9862	312.0665
19	341.5597	332.1417	320.1922
20	349.7977	309.0005	324.9405
21	331.3719	324.0049	300.9950
22	342.9078	322.8066	308.7969
23	356.8512	341.1396	299.7133
24	325.3811	338.2297	300.1644
25	338.9617	342.2803	302.2048
26	346.8411	348.9336	306.7388
27	348.5874	333.8869	313.6867
28	345.4890	330.5704	303.7563
29	347.7509	331.2365	300.7163
30	342.7702	329.4470	305.8276
31	311.9956	315.4241	318.1388
32	339.2679	336.8276	303.4402
33	340.4076	324.3234	304.1655
34	323.5303	331.9433	312.3544
35	343.1933	326.9772	315.8244
36	323.9623	332.6540	301.0035
37	337.2476	310.4066	301.3508
38	335.8955	330.7615	310.3932
39	325.7461	350.1462	298.7242
40	341.5742	330.9530	326.0157
41	326.9611	352.3338	307.7757
42	320.7690	325.3861	315.6303
43	306.6558	325.3905	312.9661

44	311.9270	337.3506	311.6120
45	308.3988	338.2297	311.8642
46	320.4525	308.3051	336.8704
47	316.9387	344.8032	339.7418
48	309.7188	318.5624	340.2142
49	322.1928	345.3020	331.5349
50	291.4183	349.9470	312.7893
51	324.8532	312.0748	315.0197
52	325.7755	331.5477	304.8803
53	308.1828	352.5167	303.2413
54	345.9879	353.8620	305.3614
55	342.7829	351.4804	323.9964
56	343.5146	334.9028	323.8633
57	335.8955	353.0368	296.2292
58	330.3746	373.7327	293.4330
59	312.7128	346.9315	289.6522
60	352.3657	321.0441	294.4037
61	343.5566	346.2120	288.4775
62	327.1556	348.4299	290.4305
63	330.9409	316.4345	303.9688
64	307.8183	329.2504	295.5870
65	323.5753	343.5319	295.7534
66	294.8984	324.4860	294.9679
67	336.1898	346.4059	291.6822
68	331.0718	353.1340	295.0040
69	318.5182	304.8529	295.6198
70	313.1609	334.1505	310.5804

7/9/91		g/m^2	
REP	SI	DO	ND
1	568.9917	715.1677	494.1415
2	582.6899	677.0910	565.3579
3	621.2778	591.9774	577.9654
4	711.3573	638.6841	551.4712
5	664.0842	722.7375	705.5641
6	683.2503	746.5099	768.4560
7	680.2920	661.8506	637.6532
8	624.1615	661.9240	462.6640
9	775.4303	560.7161	533.1175
10	659.6105	581.2883	573.2526
11	639.6031	650.1549	497.2174
12	771.3927	668.4419	467.9671
13	547.7144	633.0492	573.6259
14	677.7019	687.3575	509.3151
15	420.7320	846.4959	449.8491
16	581.1642	739.1651	353.2522

17	578.3310	795.8632	513.5182
18	433.3979	728.2852	590.1543
19	720.5361	663.4253	564.9700
20	687.5568	669.4269	561.7459
21	763.7526	710.4882	513.0862
22	666.9554	810.4627	436.8992
23	643.1164	767.3217	423.6176
24	620.1401	882.3212	373.3997
25	873.3785	679.6201	416.4338
26	643.8717	757.7403	443.9178
27	656.7373	712.4510	506.4020
28	694.0031	693.3036	485.8481
29	594.0418	632.8927	567.5703
30	533.8855	644.3029	498.2551
31	476.8726	700.1334	536.7247
32	644.1477	529.4182	487.4018
33	627.8236	574.0175	463.9184
34	625.7585	620.2971	562.1208
35	603.3269	596.4209	566.7666
36	628.2362	592.2789	499.0812
37	512.2037	687.7123	504.8178
38	596.9153	676.4755	438.3354
39	626.8072	754.8452	361.1035
40	672.9183	739.2178	469.6904
41	619.0530	700.9710	413.7602
42	517.5124	554.2646	457.9894
43	605.2422	642.6209	415.2078
44	577.3229	702.1034	513.3328
45	666.8062	471.1855	520.5930
46	618.3980	646.7836	554.0365
47	569.6614	508.3929	541.1568
48	543.1992	774.8627	578.9405
49	576.7607	626.2142	536.1465
50	746.4972	648.2447	546.3165
51	644.8360	658.1383	471.8854
52	801.1048	650.9988	451.1171
53	660.0661	664.5083	440.7456
54	665.5271	778.8796	497.2358
55	698.5653	639.1000	529.9821
56	616.1010	512.3738	525.2354
57	609.3040	621.5961	363.7744
58	678.0328	525.0951	388.7200
59	566.4065	787.8454	364.1188
60	660.5618	667.8104	400.4681
61	630.8924	609.6147	318.1269
62	556.7921	528.3251	388.4151
63	639.4871	610.8402	442.9212
64	752.6418	628.9380	333.7061

65	773.3109	612.5160	388.5757
66	579.6983	651.3688	370.8063
67	684.8846	690.3797	336.9631
68	817.9071	439.8241	372.4790
69	686.2783	634.4026	373.7957
70	768.3441	722.4121	477.3663

7/24/91		g/m^2	
REP	SI	DO	ND
1	931.8723	1360.599	640.5552
2	1022.142	1250.658	594.5721
3	1124.296	999.5136	757.5153
4	1225.342	783.3664	852.1733
5	1286.642	1051.141	798.5191
6	1046.208	1180.478	1100.313
7	1286.930	1290.197	860.4043
8	991.0234	1204.243	593.4777
9	1130.619	917.8541	612.0859
10	1098.322	1020.917	695.2386
11	1001.073	1216.779	616.3618
12	972.5914	1170.880	538.8648
13	734.8732	1333.358	605.1646
14	1055.737	1162.984	587.1281
15	562.1573	1209.678	741.4709
16	874.0404	1261.721	433.1910
17	901.2404	1149.914	660.6954
18	700.7714	1149.904	726.3277
19	1297.179	1096.745	723.5766
20	1450.969	1115.518	676.0892
21	1137.874	1369.145	571.5645
22	1077.011	1292.285	558.0603
23	1035.777	1070.766	564.0717
24	1093.991	1384.140	487.8386
25	1417.196	1106.664	510.4626
26	1019.132	1239.488	612.5814
27	1047.869	1164.334	609.7941
28	1181.617	960.2816	569.5685
29	943.1548	996.0387	822.9998
30	748.0487	1092.206	728.6803
31	628.4068	1127.985	791.5902
32	1095.181	927.4779	608.5561
33	1070.232	975.7307	611.3785
34	977.1468	1247.860	943.1129
35	935.0379	994.9117	783.1773
36	1033.675	945.8489	721.6030
37	841.1904	1178.811	584.0854
38	921.2084	1246.057	581.9241

39	978.2900	1191.103	424.1287
40	1140.622	1193.927	692.3776
41	956.2350	1201.128	543.0318
42	926.2351	909.7533	581.0646
43	937.2970	1245.621	582.4017
44	772.5707	1140.580	637.9169
45	1074.805	741.3610	680.0975
46	981.9798	1123.695	736.6343
47	966.1588	843.2762	751.0615
48	827.9240	1233.236	714.7080
49	867.9006	1016.018	843.6119
50	905.2575	1063.689	761.2475
51	898.8331	1001.201	742.6868
52	1262.406	1189.230	699.5316
53	1121.405	1156.712	662.1231
54	947.1100	1376.967	758.5745
55	1109.921	1245.065	764.7254
56	882.6343	776.5914	771.5429
57	836.4219	987.3966	478.6477
58	1109.029	1008.995	471.1298
59	796.9225	1106.887	528.5958
60	948.9908	1215.323	586.4576
61	898.9085	987.7504	339.5009
62	871.8028	977.5465	509.3520
63	1030.537	869.6836	620.3113
64	1247.526	890.6707	454.3770
65	1107.201	931.8097	509.6126
66	856.8759	1156.469	535.6799
67	1057.283	1100.380	450.4035
68	1173.904	609.0925	499.8998
69	1168.431	1045.000	487.0204
70	1268.379	1229.527	644.1118

Unionville Plant Nutrient Content
A = SI   B = DO   C = ND

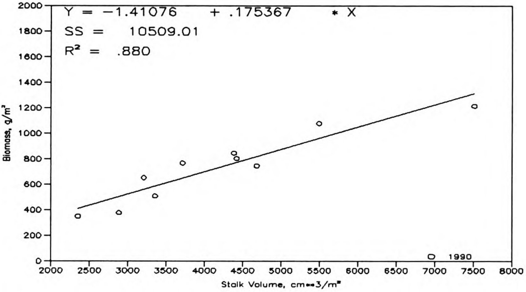
PLANT ID	DATE	N	% P	K
A	7/25/90	.93	.1	1.27
B	7/25/90	1.19	.11	1.33
C	7/25/90	.54	.06	1.14
A	8/8/90	1.02	.14	1.74
B	8/8/90	1.24	.1	1.28
C	8/8/90	.95	.08	1.27
ANI	7/11/91	1	.14	1.1
ANI	7/25/91	1.3	.19	1.25
ANI	9/ 4/91	1.4	.18	1.5
ANII	7/11/91	1.2	.18	1.16
ANII	7/25/91	1.2	.15	1.16
ANII	9/ 4/91	.9	.14	1.25
ASI	7/11/91	1.1	.13	1.15
ASI	7/25/91	.8	.08	1.33
ASI	9/ 4/91	.7	.09	.9
ASII	7/11/91	1.1	.14	1.03
ASII	7/25/91	.9	.09	1.01
ASII	9/ 4/91	.9	.1	1.17
BNI	7/11/91	1.5	.2	1.91
BNI	7/25/91	1.1	.21	1.67
BNI	9/ 4/91	1.1	.17	1.49
BNII	7/11/91	1.4	.23	1.46
BNII	7/25/91	1.5	.23	1.95
BNII	9/ 4/91	1.7	.22	1.87
BSI	7/11/91	1.3	.19	2.22
BSI	7/25/91	1.4	.23	1.51
BSI	9/ 4/91	1.1	.21	1.86
BSII	7/11/91	1.8	.32	2.01
BSII	7/25/91	.9	.18	1.83
BSII	9/ 4/91	1.5	.26	1.79
CNI	7/11/91	1.8	.31	3.46
CNI	7/25/91	1.4	.24	3.13
CNI	9/ 4/91	2.3	.28	2.71
CNII	7/11/91	2.7	.38	2.51
CNII	7/25/91	2.1	.28	3.24
CNII	9/ 4/91	1.8	.28	3.18
CSI	7/11/91	2.1	.3	2.63
CSI	7/25/91	1.9	.28	2.98
CSI	9/ 4/91	2.4	.31	4.73
CSII	7/11/91	2	.24	1.86
CSII	7/25/91	.9	.33	3
CSII	9/ 4/91	1.5	.27	3.44

Unionville Kernel Nutrient Content

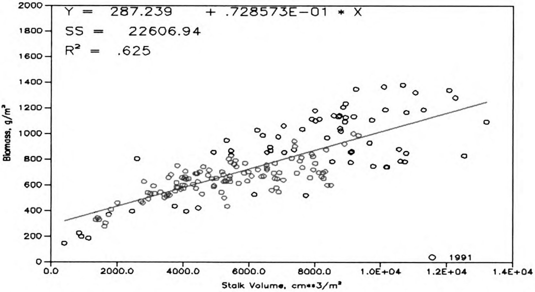
PLANT ID	DATE	N	% P	K
AN	8/8/90	1.34	.37	.33
AS	8/8/90	1.56	.4	.38
BN	8/8/90	1.46	.3	.29
BS	8/8/90	1.39	.37	.37
CE	8/8/90	1.62	.32	.31
CW	8/8/90	1.31	.32	.3
ANI	9/4/91	1.1	.34	.27
ANII	9/4/91	1.2	.34	.26
ASI	9/4/91	1.3	.36	.29
ASII	9/4/91	1.1	.35	.27
BNI	9/4/91	1.4	.38	.32
BNII	9/4/91	1.4	.52	.35
BSI	9/4/91	1.4	.42	.31
BSII	9/4/91	1.5	.43	.31
CNI	9/4/91	1.4	.39	.3
CNII	9/4/91	1.1	.44	.31
CSI	9/4/91	1.4	.34	.34
CSII	9/4/91	1.3	.42	.42

APPENDIX H

Soil Nutrient, Crop Yield, Leaf Index and Plant Biomass Statistical Analysis



1990 Stem Volume vs. Biomass



1991 Stem Volume vs. Biomass

Unionville Soil Nitrate-N Student t-Test

Year	Depth	t A to B	t A to C	t B to C
1990	0.0-0.3m	2.132	.021	.61
	0.3-0.6m	2.717	2.335	.403
	0.6-0.9m	1.568	2.611	1.158
1991	0.0-0.3m	.073	1.57	.765
	0.3-0.6m	5.004	.708	1.283
	0.6-0.9m	3.007	.538	3.452

Soil Ammonia-N Student t-Test

Year	Depth	t A to B	t A to C	t B to C
1991	0.0-0.3m	2.916	2.429	.528
	0.3-0.6m	1.382	1.614	1.208
	0.6-0.9m	.107	1.937	3.721

Soil Orthophosphate-P Student t-Test

Year	Depth	t A to B	t A to C	t B to C
1990	0.0-0.3m	4.281	14.675*	15.324*
	0.3-0.6m	2.113	.791	1.244
	0.6-0.9m	1.053	.59	.327
1991	0.0-0.3m	4.471	4.667	1.372
	0.3-0.6m	1.455	.577	1.138
	0.6-0.9m	2.114	1.342	.872

Soil Potassium Student t-Test

Year	Depth	t A to B	t A to C	t B to C
1990	0.0-0.3m	2	2.512*	5.463*
	0.3-0.6m	.107	.053	.338
	0.6-0.9m	.462	.213	1.154
1991	0.0-0.3m	.572	3.881*	2.467*
	0.3-0.6m	4.744	.132	4.296
	0.6-0.9m	1.375	2.867	.588

UNIONVILLE WATERTABLE MANAGEMENT PROJECT
STATISTICAL COMPARISON OF YIELD: 2-SAMPLE t-TEST ABOUT u
ALPHA=0.05 t(1,0.025)= 12.71

1990 REP	SI AVE YIELD mtons/ha	DO AVE YIELD mtons/ha	A to B DIFF
NORTH	2.52	2.12	.4
SOUTH	2.32	2.32	0
SUM	4.84	4.44	.4
MEAN	2.42	2.22	.2
STD			.2
n			1
t			1

1991 REP	SI AVE YIELD mtons/ha	DO AVE YIELD mtons/ha	ND AVE YIELD mtons/ha	SI/DO DIFF	SI/ND DIFF	DO/ND DIFF
NORTH	3.02	1.91	1.66	1.11	1.36	.25
SOUTH	2.9	1.84	1.7	1.06	1.2	.14
SUM	5.92	3.75	3.36	2.17	2.56	.39
MEAN	2.96	1.875	1.68	1.085	1.28	.195
STD				.025	.08	.055
n				1	1	1
t				43.4	16	3.545455

LEAF INDEX
ANOVA 7/18/90

Source	d.f.	SS	MS	F	F(0.05)
Total	209	98.41615			
Block	69	22.36283	.324099	1.086159	1.31
Treatment	2	34.87551	17.43776	58.4395	3.00**
Error	138	41.17781	.2983899		

FPRLSD Significance Test
t(0.05)= 1.96
FPLSD= .1809731

MEAN LEAF INDEX COMPARISON	DIFFERENCE IN MEAN
A to B	.8892999*
A to C	.8373225*
B to C	.0519774

LEAF INDEX
ANOVA 7/10/91

Source	d.f.	SS	MS	F	F(0.05)
Total	209	97.94504			
Block	69	26.0521	.3775666	1.027117	1.31
Treatment	2	21.16435	10.58218	28.78732	3.00**
Error	138	50.72859	.3675985		

FPRLSD Significance Test
t(0.05)= 1.96
FPLSD= .2008671

MEAN LEAF INDEX COMPARISON	DIFFERENCE IN MEAN
A to B	.5727133*
A to C	.7419019*
B to C	.1691886

Unionville Watertable Management Project
ANOVA - RANDOMIZED BLOCK DESIGN
Biomass
r= 70
t= 3

BIOMASS
ANOVA 7/18/90

Source	d.f.	SS	MS	F	F(0.05)
Total	209	5342029			
Block	69	1167149	16915.21	.9915966	1.31
Treatment	2	1820798	910399.1	53.36905	3.00**
Error	138	2354081	17058.56		

FPLSD Significance Test
t(0.05)= 1.96
FPLSD= 43.27063

MEAN BIOMASS INDEX COMPARISON	ABSOLUTE DIFFERENCE IN MEAN
A to B	179.7948*
A to C	211.4395*
B to C	31.64475

BIOMASS
ANOVA 8/ 2/90

Source	d.f.	SS	MS	F	F(0.05)
Total	209	15099709			
Block	69	4172293	60468.02	1.01536	1.31
Treatment	2	2709062	1354531	22.74485	3.00**
Error	138	8218354	59553.29		

FPLSD Significance Test
t(0.05)= 1.96
FPLSD= 80.84905

MEAN BIOMASS INDEX COMPARISON	ABSOLUTE DIFFERENCE IN MEAN
A to B	213.9255*
A to C	261.0025*
B to C	47.077

BIOMASS
ANOVA 6/19/91

Source	d.f.	SS	MS	F	F(0.05)
Total	209	60091.62			
Block	69	10295.47	149.2097	.7521629	1.31
Treatment	2	22420.52	11210.26	56.51071	3.00**
Error	138	27375.63	198.3741		

FPLSD Significance Test
t(0.05)= 1.96
FPLSD= 4.666213

MEAN BIOMASS INDEX COMPARISON	ABSOLUTE DIFFERENCE IN MEAN
A to B	4.401294
A to C	19.38433*
B to C	23.78562*

BIOMASS
ANOVA 7/9/91

Source	d.f.	SS	MS	F	F(0.05)
Total	209	2840511			
Block	69	399493.9	5789.767	.7216696	1.31
Treatment	2	1333879	666939.5	83.13115	3.00**
Error	138	1107138	8022.739		

FPLSD Significance Test
t(0.05)= 1.96
FPLSD= 29.6745

MEAN BIOMASS INDEX COMPARISON	ABSOLUTE DIFFERENCE IN MEAN
A to B	20.66543
A to C	157.7828*
B to C	178.4482*

BIOMASS
ANOVA 7/24/91

Source	d.f.	SS	MS	F	F(0.05)
Total	209	13304311			

Block	69	1461199	21176.79	.8185922	1.31
Treatment	2	8273084	4136542	159.8987	3.00**
Error	138	3570028	25869.77		

FPLSD Significance Test
t(0.05)= 1.96
FPLSD= 53.28664

MEAN BIOMASS INDEX COMPARISON	ABSOLUTE DIFFERENCE IN MEAN
A to B	88.35127*
A to C	369.8605*
B to C	458.2118*

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