The Oaks Experiments

on

Organic Management of Turf

A project sponsored by Edmonds Environmental Services &
Canada-Nova Scotia Sustainable Economic Development
Agreement

Final Industry Report

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EXECUTIVE SUMMARY

Introduction

The landscape management industry in North America, of which turf management for golf courses, parks, and commercial, institutional and residential properties is a major component, is a multibillion dollar industry. Acreage of turf is larger than that for any other single crop in the U.S. Golf course and high end residential turf receive chemical inputs equivalent to or exceeding those in intensively managed agricultural crops. Organic products and services account for probably less than 10% of total expenditures on turf management, but this is a rapidly growing sector, driven by the public concern about chemicals, increasing regulation of their use, and the necessity to find uses for unprocessed and processed organic wastes. A high level of interest in organics notwithstanding, over the last few years inconsistency in supply and quality of organic amendments, lack of experience with organic approaches, and a dearth of research into the organic approach for turf management have limited its development.

The Oaks experiments were the public demonstration element and the major component of a larger project on "Total System Organic Management for Turfs". There were two major sets of experiments at The Oaks: the Fertility Experiments, and the Mixture Experiments.

In principle, or at least so the popular literature goes, organic fertilizers are slower acting, build up fertility over long periods of time and contribute to healthier more pest and weed-resistant turfs. There is a lot of evidence to support this view in a general way. However, when it comes down to a particular situation, there are many uncertainties, and these are sufficient to discourage general use of organic as opposed to conventional fertilizers. Resolving these limitations is critical to realizing the full benefits of organic amendments; it would also help make the business of recycling organic wastes profitable, and hence to encourage more widespread, effective and private sector driven recycling and processing of organic wastes.

For organic materials to become more competitive with NPK fertilizers it is especially required:

(1) to improve predictability of their fertilizing qualities, so that they will be used as alternatives to NPK, and so that when used, they are not overused resulting in adverse side effects (such as pollution of aquatic systems and stimulation of pests), and,

(2) to document and improve predictability of their other beneficial attributes, such as their effects on pests and diseases so that users can make appropriate calculations of real cost and benefits.

The fertility experiments were designed to address these issues.

It is well documented that the success of different species or varieties grown in monoculture or in mixtures can be strongly influenced by the fertilization, mowing, water, pest, and weed control regimes, as well as by site specific variables. Thus it is to be expected that varieties, species and mixes that have been selected for use under conventional, chemically intensive management will not be the best under organic management, further that they may even perform poorly under organic management. In the mixture experiments, we compared three mixtures for their performance under low amendment and high amendment regimes. The mixes selected were ones that a priori, were considered good candidates for organic systems.

Methods

The experiments were conducted at The Oaks, an old estate in southend Halifax now belonging St. Mary's University. An old turf that had been completely destroyed by chinch bug and had acidified to pH 4.9 was rotovated, and limed. Three blocks (replicates) of the fertility experiment and two of the mixture experiment were set up on that field (the B field). One additional replicate in the fertility experiment, and one in the mixture experiment were established on a second field (the F field) that was constructed for the experiment by leveling it and importing ordinary grade top soil. The F and B fields can thus be considered representative respectively of the "instant" topsoil found in new developments, and of older, severely run down soil often found at older sites.

For the fertility experiment, a split plot design with four replicates was employed. Potato compost (0.6-1.2-0.9-32; %N, P_2O_5, K_2O, organic matter respectively), unprocessed brewery waste (5.0-1.2-0.5-78), NPK (12-3-5-0) were incorporated in large "main plots" at rates providing 11.9, 9.5, and 2 lbs N 1000 sq ft (589, 469, and 98 kg N per ha) respectively. A control main plot received none of these. Then, different levels of an organofertilizer (7-10-7-65) were applied to 2 x 2 m subplots within the Control (Cn), Compost (Cp), and Brewery Waste (BW) main plots, at rates to provide 0,1,2,3 lbs N per 1000 sq ft. The plots were seeded with "Ecomix" - a mixture of perennial ryegrass, Kentucky bluegrass and fine fescues - on May 22-25, 1992. The NPK main plots were split in two, and a blend of Kentucky bluegrasses established on one half, and Ecomix on the other, except on the F field, which was seeded only with Ecomix. Beginning in the fall of 1992, the same organofertilizer was applied as a top-dressing at an annual rate equal to that incorporated (0,1,2,3 lbs N per 1000 sq ft). Observations on turf quality variables such as greenness, verdure, species composition (including grass species, weeds and clover), winter injury, pests and diseases, leaf nutrient content and on soil properties (physical, chemical, biological) were carried out for the ensuing three seasons. Some observations were continued into 1995.

This design allowed us to determine the optimal level of organofertilizer top-dressing, and how that level might be affected by incorporating compost (a low N, bulky organic amendment), and brewery waste (a higher N amendment, on the border between a "bulky amendment" and "organofertilizer") before seeding.

Mixes examined were:

(1) "Ecomix", our own, experimental custom blend.

(2) Greenfast, an off the shelf general purpose mix widely utilized in Nova Scotia.

(3) A mix of two tall fescues. The tall fescues are gaining popularity as wear resistant species requiring lower fertility and management.

These mixes were seeded with and without white clover. Where they were grown with clover, compost was incorporated in the soil prior to seeding but no top-dressings were made subsequently. Where they were grown without clover, compost was incorporated, and plots received 2 or 3 lbs N as organofertilizer in top-dressings each year. The concept was to use clover based mixes as low maintenance mixes, relying on the clover to provide N, while regularly fertilized mixes without clovers would be the high end mixes.

In addition to these main experiments, there were a number of subsidiary experiments. In relation to the fertility experiments, these included:

- Comparison of dormant feed and early fall feed of fertilizer.

- Comparison of mulch mowing and bag mowing.

- Comparison of a liquid fish silage product with the organofertilizer as a dormant feed.

- Comparison of deleting and not deleting organofertilizer application at the 3 lb level in the third year.

- Comparison of mid-summer versus late summer application of 1 lb N at the 3 lb per annum organofertilizer level.

In relation to the mixtures experiments, these included:

- Comparison of a Kentucky bluegrass blend with Ecomix (both fertilized with NPK).

- Testing of a mixture of 35% tall fescues with 65% Greenfast. It is commonly advised not to mix tall fescues with other species; we did so following the suggestion of Talbot (1991) for ecological mixes.

In relation to both experiments, these included:

- Comparison of P nutrition between plots receiving and not receiving rock P amendments prior to seeding, and seeded with and without white clover; the concept was to test the proposition that clover plus rock P would effect improved P nutrition.

- Comparison of turf quality and soil characteristics on plots established on chronically poor turf area with and without commercial humates incorporated in the soil, and seeded with four different mixtures or blends.

The observations and some results

Observations were conducted in detail over 1992, 1993 and 1994. Selected observations were conducted in 1995. The principal types of observations and some of the results are cited below. It should be borne in mind that the F field is a relatively low fertility field, and the B field a relatively high fertility field (fall 1992 soil organic matter was 3.1% and 5.9% on control main plots for F and B fields respectively).

"Main plot" refers to the amendments incorporated in soil before seeding - none (the control), compost, brewery waste, and NPK fertilizer. "Subplot" refers to the organofertilizer subplots in which organofertilizer was applied at 0,1,2,3 lbs N per 1000 sq ft per annum.

Verdure

Verdure (biomass to cutting height) was measured in July or August of each year. On the B field, maximum verdure was reached in one year on plots receiving 3 lbs organofertilizer N and in two years on plots not receiving organofertilizer; on the F (lower fertility) field verdure equivalent to that on the B field was reached in the third year at the 3 lb organofertilizer level, but was not attained during the course of the experiment without organofertilizer.

Greenness

Greenness was ranked at 2-4 week intervals through the seasons; measurements were also made with a chlorophyll meter.

In the establishment year, greenness was affected more by main plot treatments than by organofertilizer treatments, while in 1993 and 1994, the organofertilizer treatments had stronger effects on greenness. In the establishment year, the F field greenness responded negatively to main plot amendments, while the B field responded positively to brewery waste, and NPK, but negatively to compost. In subsequent years, the F field responded strongly to amendments and the B field did not.

Of the mixtures (Ecomix, Greenfast, tall fescues) the tall fescues produced the darkest green turf in summer, however, they bleached in late fall, and were slow in greening up in the spring.

Grass species composition

Species composition on grasses (separated into Kentucky bluegrass, perennial ryegrass, and fine fescues) was examined in June 1993, and in Sept. 1994/spring 1995. Cover by clover and weeds was examined more frequently. Clover grew up in profusion from the seedbank on the B field, except in the brewery waste main plots. The clover blended well with grass on the B field. On the F field, clover developed by outgrowth from small patches and did not blend well with grass especially during the dry mid-summer period.

The pure Kentucky bluegrass stands were the most susceptible to invasion by clover.

Perennial ryegrass responded more than Kentucky bluegrass to the fertility treatments in 1992/3, but Kentucky bluegrass caught up subsequently. Perennial ryegrass persisted very well into 1995, making up 36-43% of the grass component.

Weeds were kept under control by manual weeding. Interruption of weeding for six months in 1995 resulted in large increases, the most pronounced increases being in the lower fertility blocks; the lowest weed cover in 1995 was in NPK main plots, which is attributable to their development of the highest cover by clover.

Winter hardiness

Winter hardiness indicated by winter injury and initiation of growth in the spring was assessed in late April/early May.

Organofertilizer reduced winter injury more than main plot treatments, and in 1992 dormant feed of organofertilizer more than early fall feed.

Of the mixtures, tall fescues exhibited poorest winter survival. Ecomix had more winter injury than Greenfast because of a large component of Reliant hard fescue which of all species, suffered the most winter damage in monoculture plots. The Greenfast also has a high component of Kentucky bluegrass, which exhibited good winter hardiness.

Thatch and rooting depth

Thatch and rooting depth were examined in June 1993 and October 1995. In 1993, thatch on the F field exceeded the critical thickness (12.5 mm), even after dethatching; by 1994, a reduction in thatch was observed on both fields. Between 1993 and 1994, rooting depth on the B field increased while on the F field it decreased.

Diseases and pests

Diseases and pests were monitored and when any developed to significant levels on some of the plots, all plots were examined. The most serious infestation was by red thread, which became established on the F field in mid-1993. Its abundance in 1993 was negatively affected by compost, organofertilizer, clover and mulch mowing. Very high levels of inoculum built up in the susceptible plots in 1993, and in 1994, it invaded even some of the high fertility plots; in 1994, bag mowed plots had much less. Thus bag mowing made turf more susceptible to initial infection (probably by increasing nutrient stress), but once a high inoculum built up, it reduced susceptibility.

Of the mixes, the tall fescue mix suffered most from disease, notably severe infestations of pink snow mold.

Leaf nutrients

Leaf tissues from biomass samples were analyzed for major nutrients, and some for trace nutrients and aluminum. Only F field turf had values near or below critical levels, these for N and S in 1993; Mg values of F field turf were close to or below reported critical levels. Some P values were at or close to the upper limit; the leaf data showed significantly higher %K in leaves on compost main plots, and trends for increasing K with increased organofertilizer.

Nutrient removal by bag mowing

Nutrient removal by bag mowing in selected plots was estimated and compared with nutrients recycling in clippings in mulch mowed plots in 1994 (all of the field was mulch mowed except for the bag mow plots). Bag mowing removed 3.6 lbs N per 1000 sq ft from the B field, and 0.8 lbs from the F field.

Soil physical variables

Bulk densities for main plots were determined in the fall of 1994. Water holding capacity of B and F fields were estimated in 1995, and soil moisture was monitored on selected plots in 1995. There was a trend for the NPK main plots to have higher bulk density than the other main plots.

Soil chemical properties

Soils were sampled in the fall of each years and analyzed for organic matter, pH, P, K, Mg, Ca, CEC, electrical conductivity, and nitrate. Total N was measured on some samples. Electrical conductivity increased following cultivation of the B field in 1992, and was high in the topsoil imported for the F field. Amendments increased the values further. Over time EC declined, converging on values close to 80 uS cm^{-1} in 1995, even in plots showing very high productivity.

Soil biological variables

Alkaline phosphatase activity, respiration, respiration in glucose amended soil, nitrate and ammonium production were examined in the fall of 1994. These data suggest that soil quality of the NPK main plots fell below that on control plots on the B field, but not on the F field; soil organic matter exhibited the same pattern. There was also a trend for the brewery waste soil values to be lower than those of the control. Organofertilizer had no consistent effects on the biological variables.

Implications for management (highlights)

We emphasize that while the experiments provided a lot of information, they were conducted on only one site and any recommendations for management at other sites must be considered provisional, and subject to modification by the individual user according to his or her experience with individual systems, and/or in the light of more scientific data.

Use of soil tests

Soil tests are relied on to predict requirements for nutrient supplements, usually with the exception of N. Yet rarely are the recommendation protocols calibrated for particular situations. We compared adequacy of turf nutrients as indicated by leaf tissue analysis of samples taken in mid-summer, with ratings of soil nutrients of samples taken the previous fall. These observations suggest that at The Oaks, ratings would be modified upwards for P, K and Ca, while they were about as predicted for Mg, i.e. that lower pools of these nutrients then suggested by soil tests could be maintained in the soil without loss of turf quality. This is of benefit because losses should be lower when lower levels are maintained; this is of particular concern in relation to eutrophication of surface waters. For P, we had no indication of P limitation even when the Mehlich III-P values were close to zero, suggesting that a lot of the available P is obtained from another pool of P - probably organic P. Thus where it is critical to reduce P applications, we recommend supplementing standard soil tests with leaf tissue analyses to determine whether P is actually limiting.

Electrical conductivity measurements have not been used routinely to monitor soil nutrients. Our observations and theoretical considerations suggest that EC could be employed as on site technique to identify overfertilized soils. The Oaks experiments and others suggest that soil organic matter is one of the most valuable diagnostic variables, and is a good predictor of likely response to N. (see below).

Use of compost

The experiments demonstrated several potential problems with compost applied to soil before seeding or applying sod, namely,

(1) Immature compost may immobilize N and/or exert phytotoxic properties in the first season, however these are largely counteracted by adding organofertilizer with the compost.

(2) On a soil of low biological activity (low soil organic matter), an immature compost may have very little short or long term benefit, or at least that the same benefit can be gained with top-dressings of organofertilizer; we think it is critical that composts applied to soils of low biological activity are properly matured composts as identified by appropriate tests.

(3) In very biologically active soils of higher soil organic matter, immature compost may turn over after 1-2 years and release an excessive amount of N. In such systems there may be relatively little benefit of adding composts, but if they are incorporated, rates should be less than 50 t per ha.

Use of brewery waste and similar amendments

Brewery waste, applied to soil before seeding, turned out to behave like an organofertilizer rather than a bulky amendment. As such, the application rate was very high (9.5 lbs N 1000 sq ft or 469 kg N per ha). In the establishment year (1992), brewery waste on the B field produced a lush, very healthy looking turf, however by the third year, overall quality of the brewery waste treated turf, like that of NPK plots on the B field, was lower than that of the Control; this was reflected in soil quality variables such as alkaline phosphatase activity. This was therefore an example of overfertilization with an organofertilizer, and it is likely that fertilization with other organofertilizers (organic materials with >5%N) would have similar effects. On the F field, on the other hand, brewery waste enhanced turf quality in the third year. In the first year it had a negative effect, we think because of high content of soluble nutrients in the imported top soil. These leached out after one season, leaving a poor soil thus it is important to consider both the properties of the amendments and of the soil that receive them. There was also some evidence on the B field of reduced turf quality on plots receiving top-dressing of organofertilizer at 3 lb N per annum.

Mixture and species selection

None of the mixtures that we tested was perfect. Based on the difficulties we identified, we recommend for organically managed turf a mixture of 20% Kentucky bluegrass, 30% perennial ryegrass and 50% fine fescues, with 25% each of the creeping and chewing varieties.

Managing clover

A major decision in organic turf management is whether to include or encourage, or not to include or encourage white clover. There can be little doubt that clover offers many benefits for organically managed turfs; features that we documented or have inferred from The Oaks experiment include:

(1) Presence of clover conferred greater disease resistance.

(2) Clover provided the equivalent of up to 1-2 lbs N per 1000 sq ft.

(3) Clover was probably an important factor in the effective control of broad leaf weeds at The Oaks.

(4) On the B field, clover was probably a factor contributing to maintenance of greenness through the entire growing season in 1993, 1994, and 1995.

Provision of macronutrients other than N and problems of balance

Under organic management, the key to minimizing imbalance problems is to manage the system to minimize the need for N. Then, even when fertilizing materials with near equivalent N-P-K are used, there is less likelihood of serious imbalances being created. Furthermore, the minimal use of N will also tend to reduce losses of K, Mg, and Ca by leaching, so that lower than conventional rates of application should be possible of these nutrients. The major factors involved in minimizing needs for N are:

(1) Recycling within the system (mulch mowing in the case of turfs).

(2) Maintaining cover and root density to minimize losses by erosion leaching.

(3) Inclusion of N_2 -fixing plants.

(4) Handling supplements in such a way that minimizes the possibility for a surge in the nitrate pool.

(5) Taking into account differences in supply of N from the soil, and in the accumulation of N in soil as soil organic matter.

The report offers guidelines for organofertilizer-N applications, taking into account real N requirements (likely to be in the range of 0-3 lbs N per 1000 sq ft per annum). In order to predict real N needs, we offer the following provisional guidelines:

(1) The needs for a mulch mowed turf with a mixed sward will be in the range of 1/2 to 3 lbs N per annum depending on the soil organic matter level.

(2) Bag mowing can be assumed to increase requirements by 1-2 lbs N.

(3) If clover in mid-summer is present at >50% cover, assume 1.5 lbs of N is added, and proportionally less with proportionally less cover by clover.

(4) Mature compost added to soil (circa 100 t per ha) at turf establishment, will supply 1.5 lbs or more N in the first year, and 1 lb N annually for the next two years.

(5) If turf is >40-80% Kentucky bluegrass, increase requirements by 0.5 - 2 lbs.

Management of diseases

At The Oaks, the major diseases (red thread, anthracnose) were diseases of N deficiency. Factors that made certain treatments prone to these diseases were species composition and fertility level.

Provisional strategies for maximizing resistance to initial infestation include:

(1) Ensure the presence of grass species and cultivars that are not strongly N stressed at moderate levels of N.

(2) Ensure that grass species receive adequate but not excessive N.

(3) Incorporate (new turf) or top-dress (established turf) with compost.

(4) Include clover in the system.

(5) Mulch mow.

Once inoculum is established, control infestations by:

(1) raking infected areas to remove debris, followed by (2);

(2) application of dilute soap solution to set back active inoculum remaining, followed by (3);

(3) application of organofertilizer at 1/2 - 1 lbs N;

(4) bag mowing until the conditions appears well under control.

Mowing regimes

There were dramatic declines in turf quality on bag mowed plots compared to mulch mowed plots both at modest levels of top-dressings (1 lb) and at higher levels of top-dressing of organofertilizer or NPK (3 lb). Budgets for nutrient removal showed very high removal of nutrients by bag mowing. Thus bag mowing cannot be recommend for organic management, however, bag mowing should remain an option when certain diseases become established, or if an excess of clippings (e.g. because of daily mowing) might increase winter damage.

Weeds

The most problematical weeds at The Oaks were plantain, dandelion, and violets. Weeds were kept at aesthetically acceptable levels by manual weeding, and once weeding of the initial flush following spring establishment of the new turf was completed, requirements were minimal. That first weeding requirement could have been reduced sharply by fall seeding. There is some evidence that the abundance of clover on the B field contributed to dominance of non-weed species (including clover). The data also illustrate a negative effect of verdure on weed abundance, i.e. a negative relationship to fertility. A key aspect of organic weed management is timely manual removal. When weeding was interrupted for the first six months of 1995, populations in the lower fertility blocks increased very quickly to levels that would not be aesthetically acceptable, and ultimately required a lot of manual weeding to bring them under control.

Different strategies of control may be applied to different weeds according to their life histories. For dandelions with non persistent seedbanks, plan to remove seedlings a few weeks after the major seed rains in late spring. On the other hand, for plantain it is critical to be vigilant in removing any plants that appear, as this species has a persistent seedbank and once established creates a recurring weed problem.

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FORWARD

In this the "turn-around-decade", the environment is a concern that we all must take seriously. Considering total acreage of turfgrass in urban areas, and the amount of chemicals typically used in the management of those areas, the landscape industry has a significant impact on environmental quality. As a result of public pressures, increasing regulation of urban use of chemicals, and an understanding that citizens and corporations alike must become stewards in the places they live, the landscape industry is beginning to adopt an organic approach to turf maintenance. While still in its infancy, the organic sector is rapidly growing and will have a significant impact on how our industry functions in the near future.

Edmonds Landscaping and Construction Ltd. began a transition to organic landscape management in 1989, following personnel reflection by both myself and my brother Roger. There was immediate and enthusiastic support within the company to make this transformation even though it entailed a high degree of economic risk. By switching to mulching mowers, using organic fertilizers, and adopting an IPM approach to insects and weeds, we were able to significantly reduce our use of synthetic fertilizers and pesticides on the majority of our properties. As our knowledge of the systems improved, we were able to fine-tune many of our organic approaches to the point where now many of our properties are maintained with high aesthetic quality without any use of synthetic chemicals.

In the beginning, however, there was little formal research information into the organic approach and we had to rely heavily on general literature and advice from other practitioners. As a result, our approach was very much "trial-and-error" and many costly mistakes were made. Our companies ultimate goal is the complete conversion to organic management where no synthetic fertilizer or pesticide would be used on any property, ever. We soon realized that to obtain that goal and for the organic approach to be successfully adopted, that inefficiencies and outstanding questions of the approach needed to be addressed. Furthermore, a formal, scientific basis of the organic approach would help in reducing industry skepticism and would also foster acceptance by the public.

In late 1991, Edmonds won the *Canadian Award for Business Excellence-Environment* in recognition of our innovations in the landscape field. With this recognition we were able to secure government funding and we approached Dr. David Patriquin (a well known local researcher in the area of organic agriculture from Dalhousie University) to see if he would be interested in conducting a scientific study into the organic aspects to turf management. Dr. Patriquin agreed and in spring of 1992, The Oaks Experiments were initiated.

The Oaks Experiments were the demonstration and research component of a larger project coined TSOM for Turfs. TSOM (Total System Organic Management) is a new and innovative technology for managing urban and suburban landscapes ecologically at relatively low cost. The Oaks Experiments were established to identify and address the major obstacles to the successful development and implementation of a TSOM approach to landscape management.

When searching for an appropriate site to conduct the experiments, Edmonds was fortunate to have the help and encouragement of St. Mary's University. An old turf on an estate in the south-end of the city required renovation due to devastation by chinch bug and offered the perfect setting to conduct the experiments. We thank St. Mary's University for their support, encouragement, and overall interest in the project.

It was fascinating to watch the development of the experiments over the next three field seasons. As a company, we learned new information every year and have been incorporating and testing research results as they became available. This stimulated many management questions within the company which were then incorporated into the experiments. This interaction between the researchers and the company resulted in a very dynamic project which addressed many more issues than originally proposed.

In terms of acknowledgments, for a project of this size and time-frame, the list is long. First of all, we were fortunate to be in a position to participate in the Green Plan and a large portion of this project was supported by funding from SEDA (Sustainable Economic Development Agency). We thank them for their financial commitment and overall support of the project.

Edmonds owes a tremendous gratitude to Dr. David Patriquin for his tireless work on this project. Dr. Patriquin ensured that the project was always grounded in science and because of that the results are valuable and credible. Dr. Patriquin also accepted the overall supervision of a complex and dynamic project and his personnel commitment went well beyond the day to day management of the project. Countless hours spent on four public field days, supervision of three B.Sc. Honors students, and additional consulting advice are greatly appreciated.

A key member of the project was David Reid. David's practical experience and ability to ask pertinent, challenging questions resulted in a positive and beneficial interaction with Dr. Patriquin which ensured that the theoretical and scientific aspects of the project had a strong practical application. David was also in charge of maintaining and managing the research site which was always one of the most aesthetically pleasing properties managed by Edmonds.

In 1992, we acquired the services of Brice Walsh, an Agronomist with a background in ecological soil management. Brice was placed in the position of acting as a conduit between the research team and the Edmonds office. Brice also helped to incorporate information gained from the research site into Edmonds day to day operations and to take requests and questions from Edmonds to the research team.

The list of other people directly and indirectly involved in this project is endless. Obviously you cannot successfully implement and complete a project of this magnitude without the cooperation of countless individuals. On behalf of Edmonds Landscaping, I would like to extend our greatest thanks to all those who have had a part in the successful completion of this project.

There can be little doubt that The Oaks Experiments were a tremendous success and I truly believe that this work will have a profound and lasting impact within the landscape industry. Local landscape companies and associated industries have the first opportunity to capitalize on this research and I encourage you to do so. The transition to sustainable turfgrass management is certainly not an easy one, however, it is certainly well worth the effort and this report is a first and significant step in making the transition phase less risky.

John Edmonds

PREFACE

These experiments developed out of informal interaction between myself and John Edmonds which began in 1990. I had spent 12 years researching organic farming techniques and their theoretical bases, and the Edmonds Co. were pioneering the development of an organic approach in the landscape industry. Repeatedly, in response to John's questions, I had to tell him, that there was simply no research on that topic relevant to organic turf management, or that there were general principles but they had not been tested for turfs. We finally concluded that we should do the research ourselves. With the encouragement and assistance of provincial and federal personnel associated with the Green Plan, we put together the Total System Organic Management for Turfs project, of which The Oaks experiments were the major component.

The experiments focus on two aspects of organic turf management: the use of organic fertilizer and bulky amendments, and selection of turf mixes. The Oaks experiments were intended to be practically oriented and extensive in scope so that they would find immediate application. We also wanted them to have sufficient depth or intensity that we could begin to develop a firm theoretical framework for organic turf management. It is very much to the credit of both Edmonds and the government personnel that they appreciated the relevance of the latter.

The experiments were designed to improve organic management, not to test whether it is better or worse than conventional management. An NPK reference is included, but it is there for reference to a fertilizer of well known properties. The treatment is not on its own a good example of conventional management because we did not manage it using all of the tools of conventional management.

To ensure maximum realism, the experiments were conducted under urban conditions, on much less than ideal turf, and routine maintenance was performed by Edmonds personnel using their standard procedures. It turned out that a fungal disease gained a hold on stressed plots, and threatened to demolish the whole turf. Edmonds personnel remained firm in their resolve to manage the site without the use of toxic chemicals and restricted control measures to sanitation procedures and use of mild soap solution. In the end, we maintained the credibility of the experiments as legitimately organic and learned a great deal about how fertility treatments, mixtures and grass species affect diseases. Other complications arose due to proliferation of clover, to imported soil behaving differently from the soil on site, and to heavy winter injury in the first winter. However by observing how these factors affected or were affected by the experimental treatments, we were able to greatly expand the amount of information forthcoming, and its practical relevance.

These experiments as far as I am aware are the most comprehensive set of experiments on strict organic management of turfs yet conducted. Many persons contributed to the successful completion of the research. The complications that arose generated a lot of extra work and I am indebted to Chenzghi Yang, Margaret Hope-Simpson, Ann Li Huestis, Greg Sharam, Greg MacAskill, Nathan Boyd, and Paull Grandy for responding to exceptional needs. Sarah Lawson scholarships from Dalhousie University for summer research in Botany supported participation of Greg MacAskill, Ann Li Huestis and Greg Sharam in the research. Andrew Moores, a Grade 12 student from Yarmouth, participated in the project for one month under the Shad Valley program. Dr. Stuart Hill of Macdonald College, Dr. Nick Hill of Mount Saint Vincent University, Jeff Morton of the N.S. Dept of Agriculture and Marketing, and Tim Tregunno of Halifax Seed provided useful background information and feedback. I especially thank David Reid and Brice Walsh, co-authors of the report for their spirit of teamwork, and for sticking it out until the report was completed which took nine months longer than we had anticipated. David's persistence and practical knowledge, combined with his interest in the underlying processes, were invaluable. Brice ensured that the lab work was of high quality and the final manuscript owes much to his editing skills and critical examination of results. I am grateful to John Edmonds and David Morse of Edmonds Environmental Services for allowing complete independence in the scientific endeavors while providing the stimulation of practical challenges, and for their unstinting practical support of the research. St. Mary's University personnel were always cooperative and made work at the site a pleasure. I thank Dalhousie University and the community that supports it for the privilege of being able to spend a significant fraction of my working hours pursuing this research. Finally, I thank my spouse, Nina, for her continued encouragement when those hours extended well into family time.

David Patriquin
(November 17, 1995)

ABBREVIATIONS

Cn = Control main plot
Cp = Compost main plot
BW = Brewery Waste main plot
NPK = Synthetic NPK main plot
Cn "X" = Control main plot, "X" lbs organofertilizer-N per 1000 sq ft, where X = 0, 1, 2, 3
OF = organofertilizer plots

Blk = block
MP = main plot
Sp = subplot
cv = coefficient of variation
R^2 = coefficient of determination in simple linear regression

0 = no organofertilizer applied
1 = 1 lb organofertilizer-N per annum
2 = 2 lb organofertilizer-N per annum
3 = 3 lb organofertilizer-N per annum
1b = 1 lb organofertilizer-N; bag mowed
2D = 2 lb organofertilizer-N per annum; dormant feed in November (versus 2 lb N for September in 1992/93)
2f = 2 lb organofertilizer-N per annum; fish silage substituted for Seagreen
3X = 3 lb organofertilizer-N per annum; no fertilizer applied in 1994
3A = 3 lb organofertilizer-N per annum; applied in August vs earlier
Nm = NPK treatment; mulch mowed
Nb = NPK treatment; bag mowed
Nk = NPK treatment; Kentucky bluegrass
Ne = NPK treatment; Ecomix

TF = tall fescue blend
GF = Greenfast mix
Ktb = Kentucky bluegrass blend
EM = Ecomix

ppm = parts per million
lb = pound
kg = kilogram
ha = hectare
sq ft = square feet
t = tonne

SOM = soil organic matter
EC = electrical conductivity
N = nitrogen
P = phosphorus
K = potassium
Ca = calcium
Mg = magnesium
IPM = integrated pest management
CEC = cation exchange capacity
BD = bulk density
BS = base saturation
P-ase = alkaline phosphatase

NSDAM = Nova Scotia Department of Agriculture and Marketing

<u>Note</u>

1 lb per 1000 sq ft = 48.8 kg per ha; 1 inch = 2.54 cm.
Imperial units are used to describe rates of N application and mowing heights; all other variables are given in metric units.

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I. INTRODUCTION

The landscape management industry in North America, of which turf management for golf courses, parks, commercial, institutional and residential properties is a major component, is a multibillion dollar industry (Watson et al., 1992). Acreage of turf is larger than that for any other single crop in the U.S. and golf course and high end residential turf receive chemical inputs equivalent to or exceeding those in intensively managed agricultural crops (Dynisveld, 1992; Bormann, et.al., 1993). Organic products and services account for probably less than 10% of total expenditures on turf management, but this is a rapidly growing sector, driven by the public concern about chemicals, increasing regulation of their use, and the necessity to find uses for unprocessed and processed organic wastes. A high level of interest in organics notwithstanding, over the last few years inconsistency in supply and quality of organic amendments, lack of experience with organic approaches, and a dearth of research into the organic approach for turf management have limited its development (see Box 1: What is organic management?).

Edmonds Landscape and Construction Services Ltd. began a conversion to organic management in 1989. Today, many of the properties they service are maintained totally organically with a high aesthetic quality and few weed or pest problems. In 1991, they received a Canadian Award for Business Excellence in recognition of their innovations.

The company's goal is to achieve a complete conversion to organic management where no pesticides or synthetic fertilizers would be used in any of their operations anywhere. To do so - and to make the organic approach more attractive to homeowners and to the Landscape Industry at large - inefficiencies in the system need to be reduced so that organic management is more predictable, and more efficient ecologically and economically. The Oaks experiments were the public demonstration component and the major component of a larger project on "Total System Organic Management for Turfs". There were two major sets of experiments at The Oaks: the Fertility Experiments, and the Mixture Experiments

The fertility experiments

The prominence or success of conventional N-P-K type fertilizers in turf management is largely due to two major attributes:

(1) They are convenient to handle.

(2) They have highly predictable fertilizing qualities.

BOX 1: What is *Organic* management?

The essence of organic horticulture is the achievement of high aesthetic and functional quality by enhancing natural processes, rather than by using substitutes for them (Hodges, 1982).

The word organic comes from "organismic" meaning pertaining to the whole, thus it is a whole system or holistic approach. The approach emphasizes:

> ***recycling*** to conserve resources, and add organic matter to the soil,
>
> ***diversification*** of habitat and species composition to give a good balanceof nature for pest control, water conservation, etc.,
>
> ***feeding the soil*** which, it is maintained, provides balanced nutrition and produces healthy, pest resistant plants, and,
>
> ***using legumes*** to provide inputs of nitrogen.

Using substitutes for natural materials and processes such as synthetic or highly processed fertilizers, synthetic pesticides and genetically engineered organisms is discouraged. Under strict organic management, they are prohibited. Even natural pesticides such as rotenone are discouraged; they are seen only as a last resort and necessary to use only during the transition to organic management when there are still many imbalances in the system.

The Oaks experiments are experiments in **strict organic** management: we did not use materials that would be prohibited under certified organic management except for use of synthetic NPK fertilizer on some reference plots. The results, however, have application to conventional and functionally organic systems as well as to strict organic systems. By "**conventional**", we mean systems in which synthetic or highly processed fertilizers and pesticides are used routinely. Even in those systems, natural processes are still very important and enhancing them can reduce the needs for expensive inputs, or complement the inputs to give better quality. By "**functionally organic**" we mean systems in which most of the material flows are organic, and most pest control relies on natural processes but there may be some spot or one time use of pesticides, or use of very modest amounts of certain conventional fertilizers such as superphosphate.

Following are some of the do's and don'ts of organic turf management which follow from the general principles of the organic approach (the do's) and in the case of don'ts, from those principles and requirements for strict organic management. Some of the rationale for the "don'ts" are provided.

FERTILITY

<u>Do's</u>

- Use organic fertilizers and composts.

- Use grass species and mixtures not requiring high N.

- Use a mulch mower to recycle clippings in place.

- Encourage clover (fixes N_2 from air, brings minerals up from depth).

- Assess N needs by greenness (visual), and % soil organic matter (lab test).

- Assess needs for P, K, and lime by soil tests in fall or spring.

<u>Don'ts</u>

- Do not use synthetic or processed fertilizer salts especially highly soluble N fertilizer - they acidify soil, and in excess, cause rank growth which encourages pests.

- Do not use muriate of potash (KCl). The Cl^- is slightly toxic. Use potassium sulphate, sul-po-mag or other K source (wood ash, granite dust).

WEED CONTROL

Do's

- Mow high (2.5-3 inches or 6-8 cm) to favor grasses over weeds.

- Use complex seed mixtures.

- Practice timely manual weeding followed by overseeding and mulching with compost.

Don'ts

- Do not use herbicides: they have sublethal effects on non-target plants which makes them more susceptible; they kill clover; they add to the pesticide load on the environment.

PEST & DISEASE CONTROL

Do's

- A healthy turf is more resistant to pests and diseases.

- Avoid over or under feeding grass with nutrients or water.

- Use complex mixtures.

- Dethatch and aerate as appropriate.

- Water regularly but not excessively, allow natural mid-summer dormancy or water regularly...not in between!

- Monitor pests.

- Use broad spectrum biological pesticides only when absolutely necessary.

Don'ts

- Do not use any synthetic insecticides or fungicides: they kill beneficial organisms; they treat symptoms rather than causes; they add to the pesticide load on the environment.

- Do not create stress by mid-season fertilization and then not watering sufficiently to support the growth demand.

The first attribute derives from their low volume and weight. A typical formulation might be 20-20-20, or 21-7-7. Blends can be made to give almost any desired mixture of N-P-K, thus it is possible to apply one nutrient with variable quantities of another. Organic materials contain much lower levels of N, P and K and there is much less flexibility in preparing custom blends. For example a compost may have a formulation of 1-1-0.5, a concentrated, balanced organofertilizer such as Seagreen, 7-9-7, or a material that is more concentrated in N such as blood meal, 12-2-1 (see Box 2: The use of N, P, K fertilizers on turf).

The second attribute derives from their chemical purity and consistency, the ability to blend a wide range of NPK formulations, and their high solubility. Nutrients are immediately available. Applications can be made and generally are made to saturate the biological response systems, which minimizes site to site variability. Thus one set of recommendations applies pretty generally to temperate zone turf, whether in Canada, the U.S. or Europe. The inorganic nature and high solubility of NPK fertilizers makes them fast acting and the results are seen quickly.

There are many disadvantages to the use of NPK fertilizers. However, except for burning effects in mid-summer, the disadvantages are more subtle than are the advantages, or they are not readily demonstrated, or they are matters of common resources which are difficult to cost, or the disadvantages are readily overcome by use of other inputs. There is a strong tendency to overfertilize which contributes to pollution of aquatic systems and the atmosphere (Stewart and Roswall, 1987) and can stimulate weeds (Patriquin, 1988) and pests (Patriquin et al., 1995). The concentrated, highly soluble nature of NPK fertilizers brings on quick responses in plants, but at the same time suppresses activities of microorganisms such as mychorrizae and N_2 fixing bacteria which might otherwise provide more of the nutrients from natural sources. The fast acting nature of the N components acidifies the soil which leaches cations such as Mg, K and Ca. (Uhlrich, 1987; Patriquin et al., 1993). Thus use of NPK fertilizers tends to increase the need for their use. Except for the pollution problems which are not usually monitored, and therefore not perceived as problems, most of the other difficulties can be compensated for by use of more inputs. These inputs are also convenient to use, and have highly predictable results. Lime is applied to make up for leaching, herbicides are used to control weeds, and pesticides to control insect pests and diseases. New high tech materials effect slower release of N, which increases efficiency of retention of nutrients in the system, and reduces pollution effects. With sufficient soil testing, it should in principle, be possible to make the use of conventional fertilizers environmentally safe, although they would be more expensive and less convenient to use than at present.

BOX 2: The use of N, P, and K fertilizers on turf.

Research on turfs has indicated the need generally to provide high N, low P and high K analysis in complete fertilizers for turf (Watson et al., 1992).

Potassium (K)

Potassium is particularly important in the suppression of diseases, and for drought, heat and cold tolerance of turf grasses. Much or most of the available K is held in the soil as an exchangeable cation. It is subject to high losses by leaching when it moves in the soil solution as a counter-ion to nitrate, particularly in lighter textured soils. Generally, K-related problems in turfs are ones related to K deficiency rather than K excess, although high levels of K may inhibit uptake of Mg, Ca and some trace elements. Requirements for K generally increase as the N supply increases, thus fertilizer-K application rates are commonly about one-half of those for N (Turner and Hummel, 1992).

Phosphorus (P)

It is well established that moderate levels of P in soil, or P fertilization, are critical for establishment of turf. Phosphorus also affects greenness, thickness, disease and stress resistance but not to the degree affected by N and K. Phosphorus problems in turf are ones of both excess and deficiency. High P often reduces greenness, possibly due to effects on Mg or Fe uptake and metabolism.

Phosphorus has a complex chemistry in the soil. It is highly reactive and tends to precipitate with Ca, Fe and Al, and to be adsorbed on particle surfaces. Consequently very little P occurs free in solution. A large fraction of P cycles though organic reservoirs of P which are not measured in standard soil analyses (Karlen and Sharpley, 1994). Generally, supplying P is a problem of availability rather than amount. Phosphorus is supplied in fertilizers in a readily available form, but much of that becomes largely unavailable within a year. Hence applications of P are often made at least once annually. Typical P applications recommended for turf are usually 1/10 of N recommendations, or 0.3 - 0.5 lbs P_2O_5 per 1000 sq ft per annum.

Losses of P in agricultural systems occur mainly by movement of organic and inorganic particulate material in runoff rather than by leaching of soluble P (Karlen and Sharpley, 1994). In turf systems, loss of particulate material is minimal because of the excellent soil-stabilizing properties of grass. However, where turfs are adjacent to surface waters or feed into them directly via storm sewers, the use of P-rich fertilizers may contribute to eutrophication (Ryding and Rast, 1989; Mandell, 1994). Overall, the major difficulties in regard to P in turfs are more commonly ones of excess than deficiencies.

The P and K fertilizing values of fertilizing amendments can generally be assessed adequately from the P and K contents of the amendment material and/or their effects on P and K reservoirs in soil measured by standard techniques. Provision of adequate K and P for turfs can usually be ensured by fertilizing to give medium to high soil ratings, or by applying fertilizers according to standard recommendations for different seasons. Both run the risk of applying excessive amounts. Not well understood are the minimal requirements for P and K, i.e. by how much P and K supplements could be reduced without losing quality. This is in part because we have a poor understanding of how some plant species are able to utilize "unavailable" P and K in nature, and in part because new grass selections are commonly made under well fertilized conditions; inevitably that selects for types requiring well fertilized conditions.

Nitrogen (N)

In The Oaks experiments, we examined effects of different organic fertilizer regimes on P and K in turf and soil, however, the focus was on N. Nitrogen is the fertilizer nutrient supplied in largest amounts and most often to turfs, and accounts for the largest portion of fertilizer costs. The supply of N has pronounced effects on greening and overall quality. It has subtle to strong effects on establishment, diseases and pests, stress tolerance, and competition with weeds. There are strong species effects on N needs. Nitrogen deficiency is readily discernible as poor growth and chlorotic appearance (Watschke and Schmidt, 1992; Turner and Hummel, 1992). Problems of N excess are often subtle, and not recognized, but are significant, e.g. an excess of N can increase susceptibility to certain pests and diseases (Bruneau et al., 1992), acidify the soil, and accelerate leaching losses of potassium and lime (Patriquin et al., 1993).

Nitrogen is perhaps the most difficult nutrient to manage efficiently. The readily available, inorganic forms (ammonium and nitrate) or urea (which is a very simple organic compound) are easily applied in excess but can also be readily lost by leaching or volatilization. In the soil, N is stored mainly as organic N, which is broken down by the action of soil fauna and microorganisms to inorganic N. Natural systems tend to evolve in such a way that the mixture of plant species matches the N supply (Ulrich, 1987). Under such conditions, the N supply is adequate, yet remains below 1-2 ppm in the soil solution when plants are actively growing (Russell, 1973) (Roughly, 25 ppm N in soil corresponds to 50 kg N per hectare or 1 lb N per 1000 sq ft). Under intensive culture such as in turfs, the natural supply of N from organic N compounds is generally found insufficient and supplements are provided. These often amount to several times the amount of N provided by natural sources.

Ideally, N fertilizer would be supplied in continuous small amounts just sufficient to meet needs; in practice applications are usually made once or only a few times, and in relatively large amounts. Then, problems of excess can occur, or alternatively, much of the N can be lost by leaching or denitrification. Under Maritime conditions, typical applications on professionally serviced turfs are in the range 3-5 lbs N per 1000 square feet (150-250 kg N per ha).

Much of the current research on use of synthetic fertilizers is oriented towards achieving adequacy of N supply with lower levels of applied N. This can be achieved by more frequent application of lower amounts, use of improved slow release formulations, and by calibrating soil and tissue tests to provide predictions of needs that take into account supply from natural sources.

The challenge in use of organic fertilizers is both to ensure adequacy of N and to avoid excess. Organic N is nature's slow release N fertilizer. The N supplying properties of bulky amendments is difficult to predict and is often ignored. Nitrogen availability in Milorganite (6%N), the most frequently used "organofertilizer", is estimated as 40-50% of that in synthetic N, i.e. it is considered that you have to apply twice the amount to get the same response (Moberg, et.al. 1970; Hummel and Waddington, 1981). . However, some of the unavailable N may accumulate in the soil and become available later. If this longer term accumulation is not taken into account, or if the initial application itself is excessive, over-fertilization can result just as it can under conventional management. Further, organofertilizers are often relatively rich in P and poor in K, thus continued application at rates to ensure adequacy of N could result in excessive P, but might not satisfy K requirements.

Ultimately, widespread adoption and ecologically safe and efficient use of organic fertilization methods will depend on our ability to make use of a wide range of organofertilizers and bulky amendments, tailoring their use in relation to site specific conditions and to the biological and chemical properties of the particular materials.

In principle, or at least so the popular literature goes, organic fertilizers are slower acting, build up fertility over long periods of time and contribute to healthier more pest and weed-resistant turfs (Ruben, 1989; Raymond, 1993; Carr, et.al., 1991). There is a lot of evidence to support this view in a general way, however, when it comes down to a particular situation, there are many uncertainties, and these are sufficient to discourage general use of organic as opposed to conventional fertilizers. Resolving these limitations is critical to realizing the full benefits of organic amendments (see Box 3: The distinction between "organofertilizers" and "bulky amendments"); it would also help make the business of recycling organic wastes profitable, and hence to encourage more widespread, effective and private sector driven recycling of organic wastes.

For organic materials to become more competitive with NPK fertilizers it is especially required:

> (1) to improve predictability of their fertilizing qualities, so that they will be used as alternatives to NPK, and so that when used, they are not overused resulting in adverse side effects such as pollution of aquatic systems and stimulation of pests, and,
>
> (2) to document and improve predictability of their other beneficial attributes, such as their effects on pests, so that users can make appropriate calculations of real cost and benefits.

The fertility experiments were designed to provide fundamental, scientific information related to these issues, while at the same time addressing immediate questions posed by users of organic materials as fertilizers. Edmonds had found that a high quality turf could be maintained using "Seagreen", an "organofertilizer" of 7-7-7-65 composition (%N, P_2O_5, K_2O, organic matter respectively) applied at 3-5 lbs N per 1000 square feet annually. However, the extent to which these rates could be reduced and under what conditions were not known, and supply could not be guaranteed. It seemed likely that continued application at these rates, particularly with mulch mowing, would be excessive. To the extent that applications could be reduced without losing quality, both the user and the environment would benefit.

The company also wanted to be able to utilize other types of materials. When soil is cultivated for new turf, there is a one-time opportunity to incorporate "bulky amendments" such as composts, or unprocessed organic wastes directly into the soil. In theory, bulky amendments can greatly improve soil quality and give a better rooted, healthier turf. They also provide some P, K and N, but their N supplying characteristics are influenced by many factors and can be difficult to predict.

BOX 3: The distinction between "organofertilizers" and "bulky amendments".

For practical purposes, it is appropriate to classify organic amendments in two major categories: "organofertilizers" and "bulky amendments".

Organofertilizers are materials with 5-10% N (total weight basis) and very little fibrous or humic material They are generally fine in texture and turn over relatively quickly once incorporated. Organic materials with a high percent N turn over most of their N within two years, and contribute little if at all to the buildup of soil organic matter (Mathurs and Goss, 1979). Different products behave similarly in regard to N-fertilizing properties. There are few if any inhibitory effects, and fertilizing properties are highly predictable from a simple N-P-K analysis. As a first approximation, it can be expected that 40 to 100% of the total N will be made available in one growing season, the percentage increasing with the %N of the fertilizer (Mathurs and Goss, 1979). Analysis of OM (organic matter), and ammonium or ammonium extractable on boiling would probably improve predictability of their fertilizing qualities.

Bulky amendments are materials with <5% N in their organic matter or less than 3% on a bulk basis (often the OM content is less than 50% so <5% would correspond to <2.5% on a total weight basis). They include a lot of fibrous material, and are humified to greater or lesser degrees. These materials contribute significantly to buildup of soil organic matter. Between values of approximately 1 and 3% N on a bulk basis, the N made available in the first two years is approximately proportional to N content, and varies between 10 and 40% of total N (below a value of 1-1.2% N, there is likely to be some "immobilization" of soil nitrate and ammonium when the materials are first incorporated). The soil-building value, decreases with increasing %N (Mathurs and Goss, 1979). However, the short term fertilizing value is very sensitive to the texture (particle or aggregate size), heterogeneity of the organic matter (e.g. if it is a mixture of well humified organic matter and non-humified, highly carbonaceous material as opposed to a uniformly mature compost), biological activity, and recent storage conditions. For these materials, the N-P-K content alone is a poor predictor of the material's behavior in the soil. Additional data that may be appropriate for predicting fertilizing value (e.g. as cited by Mathur et al., 1993) include:

- organic matter or carbon content
- particle and aggregate size
- germination test (indicative of phytotoxins)
- respiration (to indicate biological maturity)
- optical density (to indicate degree of humification)
- ammonium extractable with KCl
- nitrate
- salt content/electrical conductivity
- pH

The main fertility experiment involved incorporating the bulky amendments with different levels of organofertilizer (0,1,2,3 lbs organofertilizer-N per 1000 sq ft) in soil before seeding, seeding with a grass mix, and then top-dressing with 0-3 lbs organofertilizer-N annually. Control (no bulky amendments, but with different levels of organofertilizer), and N-P-K (conventional fertilizer applied at 3 lbs N incorporated) were included for comparison. To the extent that the incorporated bulky amendments reduced needs for top-dressings, they would lower the level of organofertilizer required for top quality compared to the Control plots, e.g. top quality might require 3 lbs N on the Control and only one pound on the Compost plots. The turf was seeded in May 1992, and detailed observations carried on until the end of 1994, giving an establishment (seeding) year, and two years established turf years. Some observations were continued over 1995.

Quality was assessed by monitoring greenness, verdure (the biomass to cutting height), species composition (including grass species, clover and weeds), winter injury, diseases, and pests. To help us interpret the effects of the amendments on the quality variables, and their effects on the soil, we examined the nutrient content of the vegetation, and various physical, chemical and biological characteristics of the soil. The soil and plant data were used in addition to provide some assessment of the value of soil tests in predicting turf quality and its response to amendments.

These experiments turned out to be much more complicated and required much more observation and statistical processing than anticipated. This was due to differences related to soil type (in order to add another replicate, one replicate was established on a different soil type from the other three), the germination of clover from the old seedbank on one soil type, and to some serious disease problems on certain plots of the fertility treatments. However, these complications provided a lot of additional information, and increased greatly the relevance of the experiments to practical management. We were able to document for example, how different fertility treatments affect the proliferation of clover, and how fertility and clover affect diseases resistance. On the basis of those observations, we propose provisional strategies for managing clover and certain diseases that otherwise would have been forthcoming.

Turf mixture experiment

It is well documented that the success of different species or varieties grown in monoculture or in mixtures can be strongly influenced by different fertilization, mowing, water, pest, and weed control regimes, as well as by site specific variables (Watson et. al., 1992). Thus it is to be expected that varieties, species and mixes that have been selected for use under conventional, chemically intensive management will not be the best under organic management, further that they may even perform poorly under organic management. In this experiment, (which is probably better termed a trial rather than an experiment), we compared three mixes for their performance under two organic management regimes. The mixes selected were ones that we considered before hand were likely to perform well under organic management. They were:

(1) Ecomix, our own, experimental custom blend.

(2) Greenfast, an off the shelf general purpose mix widely utilized in Nova Scotia.

(3) A mix of two tall fescues. The tall fescues are gaining popularity as wear resistant species not requiring high fertility.

These mixes were seeded with and without white clover. Where they were grown with clover, compost was incorporated in the soil prior to seeding but no top-dressings were made subsequently. Where they were grown without clover, compost was incorporated, and plots received 2 or 3 lbs N as organofertilizer in top-dressings each year. The concept was to use clover based mixes as low maintenance mixes, and regularly fertilized mixes without clovers as high end mixes (see Box 4: Clover: to be or not to be included in ecological turfs?). A previous study documented fixation of 100 kg of atmospheric N per hectare (2 lbs N per 1000 sq ft) by clover in a Halifax turf (Vessey and Patriquin, 1984).

Subsidiary experiments

In addition to these main experiments, there were a number of subsidiary experiments. In relation to the fertility experiments, these included:

- Comparison of dormant feed and early fall feed of fertilizer on spring greening up.

- Comparison of much mowing and bag mowing.

- Comparison of a liquid fish silage product with the organofertilizer as a dormant feed.

- Comparison of deleting and not deleting organofertilizer application at the 3 lb level in the third year.

- Comparison of mid-summer versus late summer application of 1 lb N at the 3 lb per annum organofertilizer level.

BOX 4: Clover: to be or not to be included in ecological turfs?

Before the advent of broad leaf herbicides, white clover (*Trifolium repens*) was a common component of turfs, whether seeded or invading naturally. With the advent of regular herbicide use in the 1950's, it was the first to disappear, and promptly became labeled a weed.

Potential advantages of clover are its nitrogen-fixing ability, greater drought tolerance than grasses, and that as a broad leaf, it competes with other (less desirable) broad leaf herbs. In a study of clover in Nova Scotia pastures and a turf on the Dalhousie University campus, it was found that clover fixed up to 100 kg N per hectare annually (Vessey and Patriquin, 1984). The drought tolerance is evident in mid-summer when clover patches on unwatered turfs remain dark green while clover-free grass browns in dormancy.

Disadvantages or undesirable features of clover that have been cited are its white flowers, that its leaves can stain white clothing, and that bees attracted to its flowers may sting children. D.G. Hessayon (1994) noted "clover is a major headache for many lawn owners. During the dry days of midsummer the bright green patches stand out against the dull and pale grass. This patchy effect is an eyesore, and control was difficult until the discovery of the newer-type selective weed killers."

We considered clover to be a desirable component of ecological turfs under low maintenance regimes, such as might be used in municipal grounds and large commercial tracts of land. In the mixture experiments, we compared mixes established with and without clover. The minus clover mixes were seeded on plots that received compost, and 2-3 lbs N of organofertilizer annually (corresponding to higher maintenance regimes). The plus clover mixes were seeded on plots that received compost initially, but not organofertilizer supplements (corresponding to lower maintenance regimes).

In addition to N_2-fixing, drought resisting, and weed suppression qualities, it was speculated that the slight acidification that occurs in the rhizosphere of clover under N_2-fixing conditions (Liu et al., 1989) might be used to mobilize phosphorus from rock-phosphate (Aguilar-Santelises, and Van Diest, 1981). Superphosphate fertilizer is prepared from rock-P by treating it with sulfuric acid to convert the more insoluble rock P to simpler, more soluble P compounds. Some plants carry out this process naturally by acidifying the rhizosphere (soil around roots) as they are taking up nutrients, which solubilizes the P. The P is immediately taken up. Legumes acidify the rhizosphere when they are utilizing nitrogen gas (from the soil air) but not when they are growing on nitrate. Phosphate mobilized by the legumes can be turned over to grasses when the tissues decompose. Thus we speculated that under a mulch mowed, low management option, clover based turfs fertilized with rock-P would have adequate P with very little potential for P losses to aquatic systems. To test combined effects of rock-P and clover on P availability, subplots were set up on the Control main plots with and without clover and with and without rock-P (see Section VII-Appendix 4).

It turned out that there was a heavy seedbank of clover in the B field, and clover appeared in abundance on the B field in 1993. On the F field, it developed as it typically does on new turfs by radiation out from a few initial plants, forming the unsightly patches described by Hessayon above. This development complicated our observations, but allowed us to document the effects of the different fertility regimes on the development of clover in turf. This information provided a basis for formulating strategies for managing clover in turfs either to avoid it or to encourage it. These are discussed in the conclusion of the report (Section IV).

In relation the mixtures experiments, these included:

- Comparison of a Kentucky bluegrass blend with Ecomix.
- Testing of a mixture of 35% tall fescues with 65% Greenfast (it is commonly advised not mix tall fescues with other species; we did it following the suggestion of Talbot (1991) for ecological mixes).

In relation to both experiments, these included:

- Comparison of P nutrition between plots receiving and not receiving rock P amendments prior to seeding, and seeded with and without white clover; the concept was to test the proportion that clover + rock P would effect improved P nutrition (Section VII-Appendix 4).
- Comparison of turf quality and soil characteristics on plots established on chronically poor turf area with and without commercial humates incorporated in the soil, and seeded with four different mixtures or blends (Section VII-Appendix 5).

Format for presenting results

The fertility experiments involved a large number of observations or dependent variables (color, verdure, species composition, disease, winter injury, soil variables), independent variables (the different incorporated amendments, and different levels of top-dressings) and as it turned out, a number of quasi independent variables or covariates (the different soil types, clover, disease). To simplify description and interpretation of results, we present results and discuss them separately for each turf quality variable (Section III.1A-H) followed by the soil variables (Section III.1I). These sections are more or less self contained, and can be read separately. In the final results section, the relationship of leaf nutrients (presented in Section III.1G) to soil variables (Section III.1J) is examined to determine whether soil tests are predictive of plant nutritional status. However, the bulk of the discussion dealing with interactions between these different sets of variables and the practical implications is given in Section IV (Discussion and Implications for Management). The results section is written primarily for the scientific reader. The non scientific reader may wish to skip directly to Section IV, which is written for both scientific and non scientific readers. Both sets of readers should read Section II on the design of the experiments, and the first three paragraphs of the results section which will assist in reading graphs and tables.

II. THE EXPERIMENT SITE, AND DESIGN OF THE EXPERIMENTS

To reduce costs and to ensure that the results were seen as applicable to the industry, we wished to conduct the experiments in an urban setting, and to maintain them by normal procedures used by Edmonds on commercial properties. To be credible as experiments in *organic* management, there could be no use of pesticides, no matter what the difficulty. With the cooperation of St. Mary's University, we were given access to turfs at "The Oaks" an old estate in south end Halifax which is now part of the St. Mary's University campus. There are two large turf areas at The Oaks (Fig. II.1): the "B field" behind the house, and the "F field" in front of the house. The F field was established in the spring of 1992 on top of fill by leveling it and adding a 6 inch (15 cm) layer of ordinary grade topsoil that had been enriched with lime and soluble nutrients. The old B field turf had been completely destroyed by chinch bug (Photo 1b) and the soil strongly acidified (pH 4.6-4.9; Table II.1). Soil depth varied between 3 and 9 inches (7.5 and 23 cm). The field was rotovated (May 3) and limed (May 12) with a mixture of coarse and fine dolomitic lime (Table II.1). The F and B fields can be considered representative respectively of the "instant" topsoil found in new developments, and of older, severely run down soil often found at older sites.

Amendments were made to the soil on May 16-21, 1992 and grass seeded on May 22-25. Observations were carried on through the ensuing three field seasons (1992, 1993, 1994). Plots were marked with buried posts, and except for the application of fertilizers, conducting scientific observations, and bag mowing of sixteen 2 x 2 m plots separately from the rest of the area (which was mulch mowed), the site was maintained by normal commercial procedures used by Edmonds. That involved weekly mowing (grass cut at 2.5 inches with a 19" and 21" Troy Built mulching mower), aeration and dethatching (both in the spring of 1993, and aeration in early November of 1993), manual weeding, and overseeding (1992, 1993). Dethatching in the spring of 1993 was conducted to remove winterkilled grass prior to overseeding. No herbicides or other pesticides were applied over the three years of the experiments. A 3% Safer Soap soap spray was applied to the B field in 1993 in an effort to set back a potential infestation by chinch bug (it did not materialize) and to selected areas on both fields in 1993 and 1994 in an effort to reduce infestations of red thread, a fungal pathogen.

The fertility experiments

In the fertility experiments, we examined the influence of bulky soil amendments applied to the soil before seeding, on the need for annually applied organofertilizer and at the influence of both types of amendments on turf quality and soil properties.

The bulky amendments and the organofertilizer "Seagreen" that we used were ones which were readily accessible locally when the experiments were established. The bulky amendments, which were applied to "main plots" (Fig. II.2), were:

(1) Unprocessed brewery waste (spent grain). This material was provided fresh from a local brewery. It was applied at a rate of 7.23 liters of fresh material per square meter to give an intended N application of 300 kg N per ha (6 lbs N per 1000 sq ft), based on analysis of an earlier batch. However, N content of the actual batch used proved to be higher (Table II.2), and the actual application was 469 kg N per ha (9.6 lbs N per 1000 sq ft). Analytical data are given in Table II.2.

(2) Potato compost. In 1991 and 1992, large volumes of potato compost were available following composting of potato culls from fields suspected to be infected with tobacco mosaic virus. The compost had been prepared in Prince Edward Island in 1991 from potato culls, farmyard manure, sawdust, and wood ash, using a windrow method with turning 2-4 times. It was applied to give a one inch cover of the soil (before incorporation), which is a fairly typical rate of application for composts. This rate corresponded to 98 tonnes dry matter and 589 kg N per hectare (12.1 lbs N per 1000 sq ft). Analytical data are given in Table II.1.

These were compared with:

(3) Synthetic NPK fertilizer. Urea (44-0-0), superphosphate (0-20-0), and potassium sulfate (0-0-50) were applied to give 2, 3, and 6 lbs of N, P_2O_5, K_2O per 1000 sq ft which were the rates recommended on the basis of soil analyses for the B field.

(4) No Amendment. The control treatment.

After spreading the bulky amendments, all plots were rototilled.

The annually applied organofertilizer was "Seagreen" (7-7-7), a fish based fertilizer from National Sea Products Ltd., applied at rates of 0,1,2 and 3 lbs N per 1000 sq ft per year to 2 x 2 m subplots. Initial applications at these levels were spread on soil in the subplots just before seeding, and incorporated to a depth of 10-15 cm (4-6 inches) using shovels. Then the whole area was seeded with "Ecomix". Subsequent top-dress applications were made two or three times annually beginning in the fall of 1992 (Table II.3). The NPK main plots were top-dressed with 3 lbs N annually with synthetic fertilizer, with 1 lb applied in spring, 1 lb in mid-summer and 1 lb in the fall.

There were four blocks (replicates) of the main plots (Fig. II.2). Each of the initial subplot treatments (0,1,2,3 lbs N per annum) were replicated twice in each main plot. These treatments are designated OF0, OF1, OF2 and OF3 or the prefix Cn, Cp or BW is used to indicate specific main plot treatments (Control, Compost and Brewery Waste). For the purpose of researching questions raised by company personnel after the start of the experiments, one of the two replicates at each of the 1,2 and 3 lbs levels was subsequently utilized for another treatment which was compared to the original treatment on the unaltered plot. These comparisons constituted "subsidiary experiments" (Table II.4)

Turf mixes for organic management

The mixtures (Table II.5) were:

(1) "Greenfast", an off-the-shelf, general purpose mix, sold by Halifax Seed.

(2) "Ecomix" a custom blend which essentially followed a mix of species recommended by ecological turf managers in the U.S. (Talbot, 1990) modified as suggested by Tim Tregunno, Halifax Seed. Talbot's suggestions for ecological mixes for northern new England are: (i) Kentucky bluegrass: up to 30% or even 50% if you mix several improved varieties and are planting in full sun; (ii) perennial ryegrasses: 20-25% or 15% in colder regions; (iii) fine fescues: at least one red fescue, one chewings fescue and one hard fescue for a total of 50%; (iv) coarse (tall) fescues: 20%.

(3) Tall fescues: a blend of two tall fescue cultivars. This mix was recommended by Tim Tregunno as one that might perform well under ecological management, also because the tall fescues were receiving increasing attention within the turf industry.

In addition two other mixes were tested:

(4) On the NPK main plots on the B field, subplots of a Kentucky bluegrass blend (two cultivars) were established to compare with Ecomix on the NPK main plots.

(5) In the fall of 1993, a mixture of Greenfast and 35% Tall fescues was seeded on three newly cultivated plots.

Composition and seeding rates of the mixes are given in Table II.5. The grass mixes (1), (2), and (3) were seeded with and without clover seed. Where they were grown with clover, compost was incorporated in the soil prior to seeding but no top-dressings were made subsequently. Where they were grown without clover, compost was incorporated, and plots received 2 or 3 lbs N as organofertilizer in top-dressings each year.

Observations

Observations on the plots included standard soil tests, measures of biological activities of soil, and various measures of turf quality, including greenness ranked visually and with a chlorophyll meter, top (clippings) and bottom up biomass, compression resistance, nutrient content, cover by clover and weeds, and ratings for diseases. The methodologies are described in the relevant sections below. Observations on the organofertilizer plots were conducted on the inner 1.5 x 1.5 m of these 2 x 2 m plots.

Table II.1. Results from analyses of soil samples taken before applying treatments, lime recommendations and lime application[1].

Soil	**Oaks B field**	**Oaks B field + compost (6:1)**	**Oaks F field topsoil**
Date Taken	**May 1**	**May 1**	**May 8**
Org. Matter %	3.8	4.6	2.7
pH	5.5	5.3	7.1
pH in buffer	6.0	6.2	-
Our pH	4.9	5.45	7.3
Our EC (uS/cm)	78	500	930
Our NO3 (ppm)	20	75	25
CEC (meq/100 g)	13.9	12.2	8.6
P (ppm)	30H	93VH	113VH
K (ppm)	48VL	315VH	313VH
Mg (ppm)	24VL	60VL	152M
Ca (ppm)	306VL	267VL	1137M
% Base saturation	13.3	10.9	32.8
K (% of CEC)	0.9	6.6	9.4
Mg (% of CEC)	1.4	4.1	14.8
Ca (% of CEC)	11.0	10.9	66.5
H (% of CEC)	86.6	78.4	9.4
S (ppm)	17H	26VH	58VH
Zn (ppm)	10.8VH	15.2VH	5.0H
Mn (ppm)	11L	14L	36H
Fe (ppm)	93VH	96VH	37H
Cu ppm	3.3VH	3.0VH	1.6H
B ppm	1.2M	1.7H	0.4L
Recommended Lime	6.5-8 T/A (--pH 6/6.5)	5.0-6.5 T/A (--pH 6/6.5)	none-
Recommended N	2 lbs/1000 sq ft		2lbs/1000 sqft
Recommended P	3 lbs/1000 sq ft		0/1000 sq ft
Recommended K	6 lbs/1000 sq ft		0/1000 sq ft

[1] Composite soil samples from the top six inches of the B and F fields were prepared, and analyzed by a commercial lab. Potato compost was added to a second sample of the B field in a ratio of 1 part to 6 by volume, to simulate the addition of potato compost in the field. The lime requirement given by the commercial lab was for 6.5 to 8 tons/acre to bring the pH to 6 to 6.5 respectively; with compost added, the estimates are 5.0 to 6.5 tons/acre lime. They advised not to apply more than 4 tons/acre initially.

Lime applied 8 tons/acre of lime were applied to the B field, 4 tons/acre as fine dolomitic limestone (by sieve analysis, 25% <180 u; 52% was 90-180 u) and 4 tons/acre as coarse limestone (86%>2mm). It was anticipated that this would provide a long term supply of lime without overliming in the short term. Analysis of the topsoil spread on the F Field indicated no requirement for lime (above).

Table II.2. Chemical composition of organofertilizer "Seagreen" and bulky amendments used at The Oaks. Values are on dry weight basis except dry matter%, and BD (bulk density).

Components	Potato Compost		Brewery Waste		Organofertilizer	
	Supplier data	Our anal.	Prev. batch	Oaks batch	Supplier data	Our anal.
Total N %	0.6	0.60	3.1	5.0	7.06	7.1
Organic C %	13.4	16.0	26.1	38.9		32.5
C:N	22.3	26.7	7.6	7.8		4.6
DM %	65	52		24.6		
BD g dry mL^{-1} fresh		0.387		0.130		
pH	6.8	7.9		5.0		7.4
EC (uS.cm^{-1})[a]		7000		650		4800
NO_3-N		120				
P%	0.32	0.51	1.35	0.53	10.85	4.16
K%	0.46	0.72	0.050	0.4	6.44	5.60
Mg%	0.11	0.36		0.24	0.23	0.25
Ca%	0.53	1.20		0.45	9.60	11.2
S%		0.14		0.20		0.54
Fe%		1.23		0.10	0.024	0.05
Mn ppm		503		69	8	16
B ppm		9		5	13	12
Mo		1.0		10		1
Na%	0.6	0.07		0.02		2.0
Heavy metals (ppm)						
As		2		<2		5
Cd		0.3		0.2		0.3
Cr		14.8		50		5
Co		12.5		4		1
Cu	3.7	26		157	6	5
Pb		11		4		4
Hg		0.05		<1		<1
Ni		11		40		1
Se		0.15		0.2		0.3
Zn	19.5	191		115	52	51

[a] Value for a 1:1 w/vol water.

Table II.3. Levels of organofertilizer and other treatments applied to subplots. Numbers represent lbs of organofertilizer-N per 1000 sq ft.

			1993			1994	
Subplot	Initial	Fall 92	Spr	Summ	Fall	Spr	Summ
OF0	0	0	0	0	0	0	0
OF0	0	0	0	0	0	0	0
OF1	1	0.5	0.5	0	0.5	0.5	0
OF1	1	0.5	0.5	0B*	0.5B	0.5B	0B
OF2	2	1	1	0	1	1	0
OF2	2	1D*	1	0	0.75 F*	1	0
OF3	3	1	1	1	1	1	1
OF3	3	1	1	1 A*	1	0X*	0X

Letters designate subsidiary treatments as follows:

B = bag mowed from July 17, 1993 onwards,
D = dormant feed, applied on November 6 versus September 8 for others,
F = liquid fish silage substituted for organofertilizer; applied at slightly lower rate because of the volume of liquid limited higher rate (7.5 liters of 0.78% N stock diluted 1:4),
A = applied on Aug 17 versus July 6 (normal time),
X = no organofertilizer applied in 1994.

Plots to which these subsidiary teatments were applied were chosen at random from the pair of plots within each main plot.

Dates of fertilizer applications and NPK formulations:

Initial: May 20, 1992 organofertilizer and NPK were incorprorated in soil; NPK: urea (44-0-0) superphosphate (0-20-0) and potassium sulfate (0-0-50) were applied to give 2,3,6 lbs N, P_2O_5 and K_2O per 1000 sq ft which were rates recommended on the bais of soil analysis for the B field.

Top-dressings of organofertilizer and NPK

Fall 92: Sept. 8; Nov 6 for dormant application (D); NPK: 12-3-5 SCU formulation.

Spring 93: May 18 (NPK: 10-10-10).

Summer 93: July 6; Aug 17 for treatment OF3A.

Fall 93; Nov. 17 NPK: 12-3-5 SCU formulation.

Spring 94: June 3. NPK: 10-10-10.

Summer 94: July 1, NPK: 10-10-10.

Table II. 4. The subsidiary fertility experiments.

(1) Comparison of organofertilizer applied in the late fall ("dormant application") with organofertilizer applied in early fall: for this comparison, application of the fall fertilizer to one of the OF2 replicates in 1992 was delayed until November 6; other plots received fall fertilizer on September 8. Observations to test the differences between these two treatments were made in May, 1993.

(2) Comparison of early versus late summer application of organofertilizer: for this comparison, application of 1 lb N per 1000 sq ft organofertilizer to the OF3 plots was made on July 6, 1993 for one of the replicates, and on Aug. 17, 1993 for the other replicate. Observations to test the differences between these two treatments were made in July, 1993, and subsequently.

(3) Comparison of mulch mowing versus bag-mowing: for this comparison, one of the OF1 replicates was bag mowed separately from the rest of the turf (which was mulch mowed), beginning on July 17, 1993. Observations to test the differences between these two treatments were made over the remainder of the experiment.

(4) Comparison of dormant liquid fish silage fertilizer with dormant applied organofertilizer for their effects on early spring greening; for this comparison, fish silage fertilizer produced by Biotherm International from salmon aquaculture wastes was applied in place of organofertilizer to one of the OF2 replicates in the late fall of 1993. Observations to test the differences between these two treatments were made in April and May, 1994.

(5) Comparison of no organofertilizer application in the third season to OF3 plots with regular application to OF3 plots; for this comparison, no organofertilizer was applied to one of the OF3 subplots in 1994. Observations to test the differences between these two treatments were made subsequent to the May 27, 1994 fertilizer application.

The subplots for these new treatments were chosen at random. Except for the bag mowed treatments which were maintained until the end of the experiment, it was assumed that the new treatment effects were transient, and that overall, they would not cause persistent differences from the original treatments after the regular treatments were resumed.

Table II.5. Species and cultivars in the turf seed mixes and blends used at The Oaks.

1. "**Ecomix**" (6 lbs seed/1000 sq ft)

-Chewing fescue (Koket and Wilma), 15%
-Creeping red fescue (Fortress), 10%
-Hard fescue (Reliant, a high endophyte type), 35%
-Kentucky bluegrass (Haga), 20%
-Perennial ryegrass (Palmer), 20%

2. **Tall fescues** (7 lbs/1000 sq ft)

-Rebel Jr, 50%
-Tribute, 50%

3. Halifax Seed **Greenfast** (Standard Shelf Mix);
applied at 4.6 lbs/1000 sq ft):

-Kentucky bluegrass (Haga), 40%
-Chewing fescue (Koket), 15%
-Creeping red fescue (Fortress), 15%
-Perennial ryegrass (Palmer), 30%

For plus clover plots, clover was added at a rate of 0.1 lbs per 1000 sq ft

4. On the NPK main plots, **Kentucky bluegrass** (50% Haga, 50% Gnome; 3 lbs/1000 sq ft) was planted on large subplots; the rest of the main plot had Ecomix.

5. **Greenfast + tall fecsues.** A mix of 65% Greenfast and 35% tall fecsues applied at a rate of 4.6 lbs/1000 sq ft.

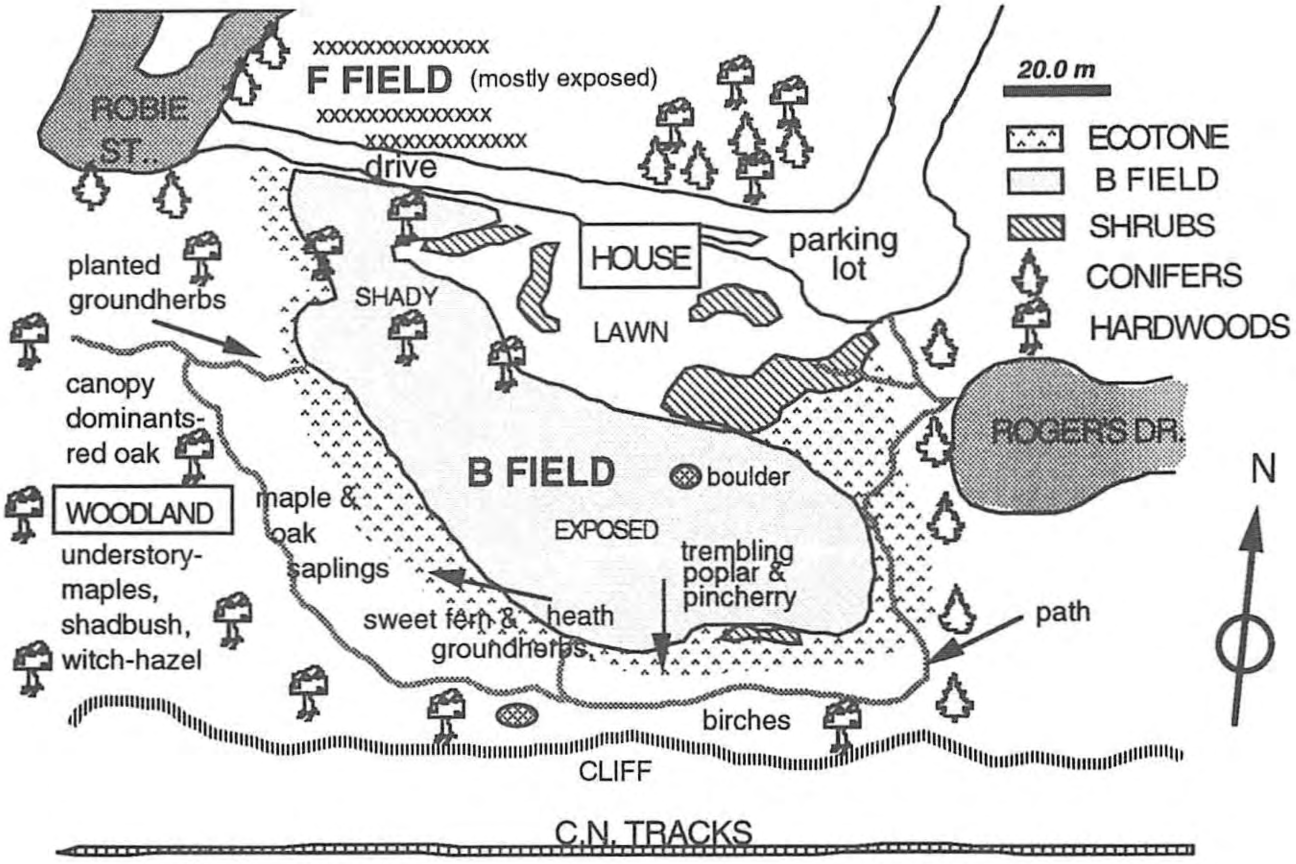


Figure II.1 Diagrammatic illustration of major vegetation types surrounding the B (back) field at The Oaks, and location of the F (front) field. The area of the B field is approximately 2000 m^2, that of the F field (not detailed in the diagram), 1200 m^2.

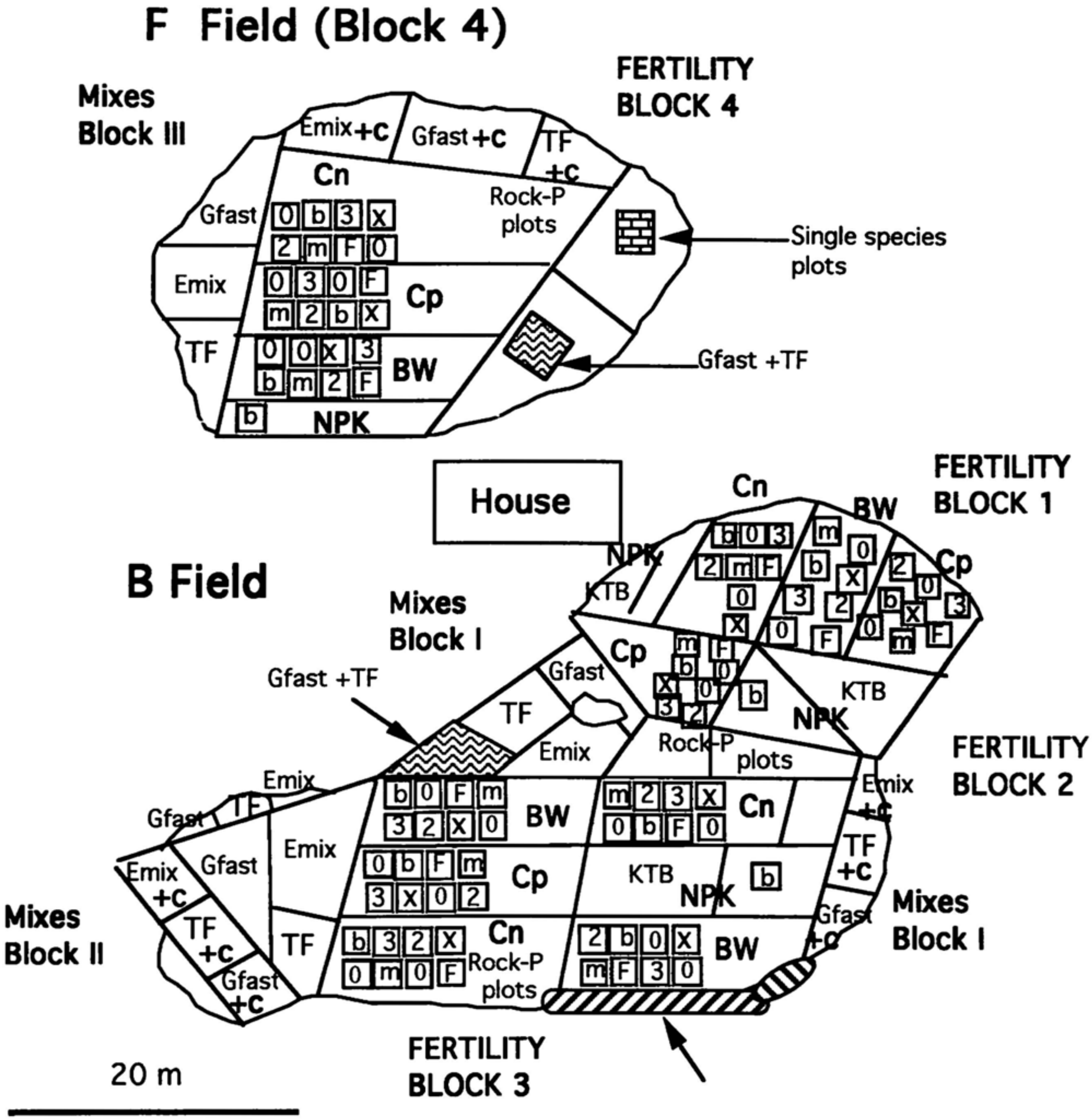


Figure II.2. Diagram of plots at The Oaks. Main plots are NPK (synthetic fertilizer), Cn (Control), Cp (Compost), and BW (Brewery Waste). Small squares are the organofertilizer subplots with treatments as modified in 1993/4: 0 = no organofertilizer; m = 1 lb N per 1000 sq ft per year; b = 1 lb N, bag mowed; 2 = 2 lbs N; F = 2 lbs N, liquid fish used in place of organofertilizer in the fall of 1993; 3 = 3 lbs N; X = 3 lbs N but no fertilizer applied in 1994. Mixes are TF (tall fescues), Gfast (Greenfast), Emix (Ecomix); +c refers to clover overseeded. Ktb refers to areas seeded with Kentucky bluegrass. Scale bar applies to Blocks and main plots. Subplots are 2 x 2 m.

III.1. THE FERTILITY EXPERIMENTS

After the first month, the turf on the B field (Blocks 1-3) and F field (Block 4) differed in overall appearance and responded differently to treatments. We had not anticipated that there would be a strong interaction between soil type and effects of different treatments, however given that there were and that there were large differences in soil properties (Section III.1I), it would be misleading to describe the results in terms of averages for the four blocks. Hence we present results separately for B and F fields. There was only one replicate of each main plot on the F field, thus statistical generalizations cannot be made about main plot effects on the F Field. In general, below, we examine the replicated data for the B field, and comment on whether there was a "trend" for similar differences or similarities between main plots on the F field. The subplot treatments were repeated once or twice on each of the Control, Compost and Brewery Waste main plots allowing calculation of statistical data for the subplot effects on the F field when it appears reasonable to assume that there are no substantial interactions between subplot and main plot effects (which could be assessed for the B field).

Graphical presentation of data and statistical tests

For graphical presentation of the data we have followed the following general scheme, illustrated by the data for verdure (turf biomass to cutting height) in 1993.

The data for the B field and F field are presented as separate graphs on the left and right side respectively of each panel. The top panel gives the values for the organofertilizer subplots averaged for all main plots on which organofertilizer subplots were located, i.e. for the Control, Compost and Brewery Waste main plots. These values are presented left to right in order of increasing level of organofertilizer, designated by numbers 0,1,2,3. Next to those are given data for subplots which were altered in some way - in this case 2D refers to organofertilizer applied at the 2 lb level, but in the fall of 1992 it was applied as a dormant feed rather than as an early fall feed as was done for the other plots. 3L refers to a variant at the 3 lbs level. The variant treatment is identified in the legend.

The next three bars, give the average values for all subplots except the variants, for each main plot, Cn referring to Control, Cp to Compost and BW to Brewery Waste. So the bar Cn represents the average value for the subplots receiving 0,1,2,3 lbs N per annum organofertilizer on the Control main plot, the bar Cp the average value for the same subplots on the Compost main plot and so on.

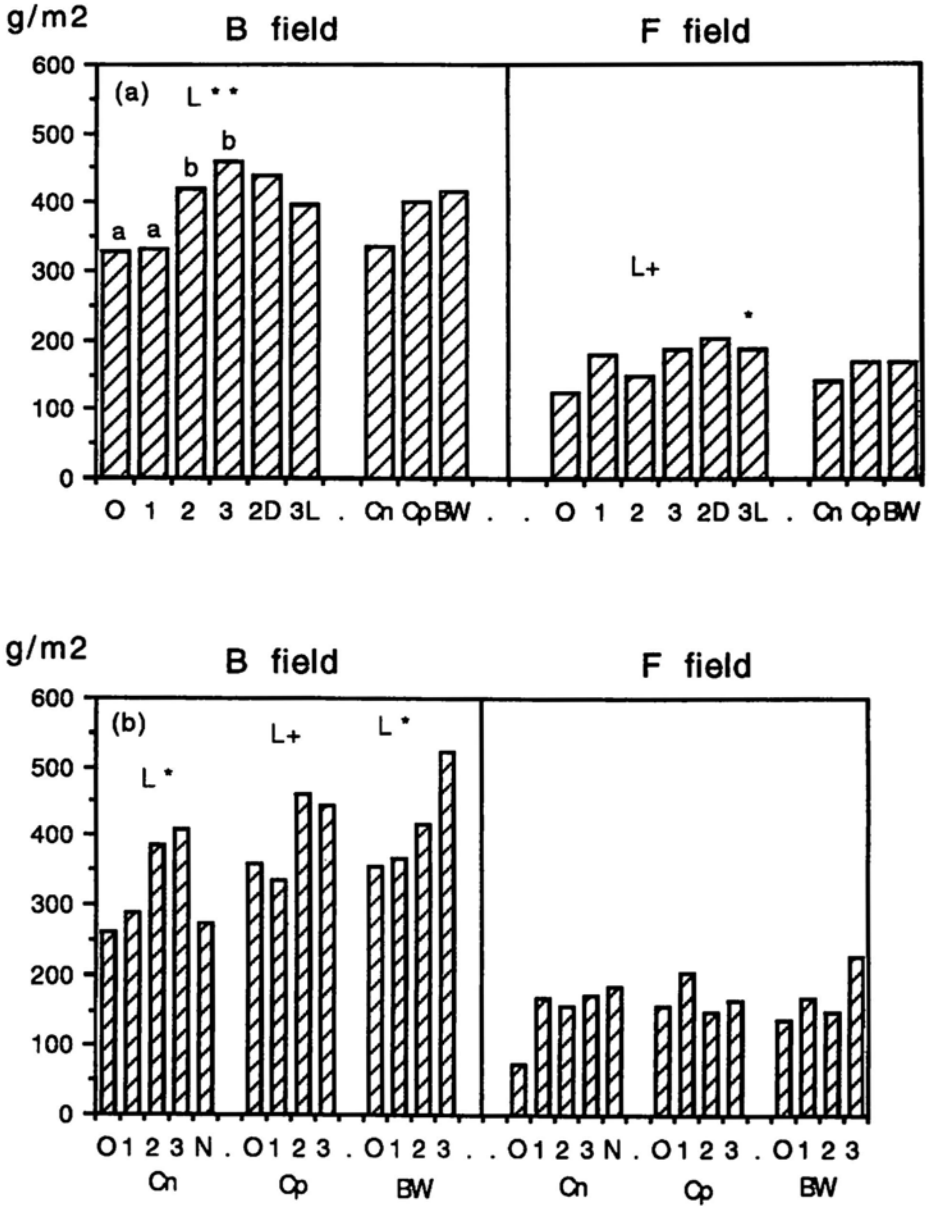
These two sets of data are intended to convey:

(1) the overall trends for differences between subplots regardless of the main plot on which they occur, and,

(2) the overall trends for differences between main plots regardless of the subplot effects.

The bottom (b) panel gives the breakdown of the same data for each main plot, but without the variant plot data. The value (bar) for the NPK main plot is shown next to the Cn3 bar, so that a direct visual comparison can be made between NPK applied at 3 lbs N and organofertilizer applied at 3 lbs N and at other levels on the Control main plot.

In the text, highlights of results are prefixed with "bullets".



<u>Statistical tests</u>

The letters above the bars indicate statistical differences between treatments at the 0.05 level of probability, as indicated by Fishers Protected LSD test (applied only when the ANOVA indicates a significant treatment effect; the ANOVA F values and corresponding probabilities are given below the figures). When there are no letters, the overall ANOVA test was not significant. When there are letters, treatments that do not share a letter are significantly different. In the case of panel (a) for the B field, verdure for the OF0 and OF1 plots differed from those for OF2 and OF3. The variant treatments were compared only with the corresponding non variant treatment at the same level of organofertilizer. If there was a significant difference, it is indicated by +, *, **, corresponding to $\alpha = 0.1$, 0.05 and 0.01 respectively.

The organofertilizer 0,1,2,3 lb N treatments were tested for linearity of response (i.e. whether the response increased and by approximately equivalent increments as application rates increased) and for a quadratic, saturation type response (i.e. whether response increased to a maximum and then decreased at higher values), using the single degree of freedom linear contrast tests in the SUPERANOVA program. A significant linear response is indicated by "L" with the degree of significance indicated by the same notation as above (+, *, **). If there was a significant quadratic, saturation type response it is indicated by a "Q". If both types of responses were significant, only the one with the higher significance value is indicated.

In the case of the B field, the pertinent ANOVA was a split plot for data in the top panel and RCB ANOVA for the bottom panel. For the F field, a RCB ANOVA was applied to the data represented in the top panel, assuming that there is no interaction between main plot and subplot effects - in effect the different main plots are treated as replicate blocks. No ANOVAs were conducted for the data in the lower panel as they are unreplicated, however the responses to organofertilizer were tested for linearity and quadratic saturation type response by regression analysis.

Units

For the convenience of landscape personnel who do most of their calculations in lbs per 1000 sq ft, we have given fertilizer application rates in those units. When it is stated that an organofertilizer is applied at the 1 lb N level, that means 1 lb N per 1000 sq ft per annum. Cutting heights are given in inches. Other units are metric. Roughly, 1 lb per 1000 sq ft is equal to 50 kg per ha. A separate table of abbreviations is given on page xxx for easy reference.

A. Verdure and clippings

The above ground biomass can be considered to be made up of two components: the "verdure" (Skogley and Sawyer, 1992) which is that below mowing height, and the "clippings" which vary in amount over a mowing interval from zero just after mowing to some maximum value just before mowing. In an established turf, the verdure is a function mainly of turf thickness, which is an important quality parameter and is influenced by longer term factors such as winter injury, soil depth, compaction etc. The clipping yield is a function of the verdure, and of the photosynthetic activity per unit of verdure and may be influenced strongly by shorter term factors such as drought.

In the first year, total above ground biomass was measured just before the first mowing (June 30, 1992); this is considered "seedling biomass". It was measured again on August 20 shortly after mowing and is thus a measure of the verdure. In mid-summer of the second and third years, total biomass and clippings (grass sheared at mowing height) were measured one week after mowing; verdure in these cases was calculated by subtracting clipping weight from total biomass.

Methods

Turf was cut at 1 cm above the soil with good quality garden shears. On June 29, 1992, samples were taken from one 35 x 35 cm quadrat and on August 19, 1992, from two 25 x 25 cm quadrats placed in each subplot. Two quadrats were placed in the NPK main plots. Samples were dried at 80 °C and weighed.

On July 13, 1993, grass swaths of 55.7 cm^2 each (the area covered by clippers) were taken in each 1.5 x 1.5 m subplot, from two positions at 1 cm height (total leaf samples) and from five positions at 6.5 cm height (clippings). Samples were taken in locales within the subplot that were at least 25 cm from any clover. The clippings weight per unit area was subtracted from the total weight to give verdure. Two 1.5 x 1.5 m quadrats were placed in the NPK main plots and sampled in the same manner.

On August 10-11, 1994, three swaths of 48 cm^2 each were cut at 1 cm above the soil at three random locations in each subplot. Presence or absence of clover was noted, and minus clover samples put in one bag, plus clover in another. Then, three more swaths were cut to give a total of three cut from grass-only areas (minus clover or grass only samples) and as possible, three from grass plus clover areas (plus clover samples). To qualify as a minus clover sample, it had to fall within a 50 x 50 cm area free of any clover . For clippings, six swaths were cut initially at 6.5 cm, then six more to give a total of six minus and six plus clover as above. Two 1.5 x 1.5 m quadrats were placed in the NPK main plots and sampled in the same way. Verdure was calculated for grass-only and grass plus clover areas separately. Twenty-one of the 213 clippings samples were lost in processing. Values of verdure for these samples were estimated from the total biomass using regressions of verdure on total biomass for other samples within the same categories (adjusted R^2 values 0.95-0.99, $p<0.001$). To determine tiller density, the number of tillers was counted in separate samples of two swaths from each selected treatment.

Biomass changes in verdure over three years

Changes in verdure over the three years (Fig. A1) provide some indication of whether the turf approached a mature state over the period of observation, and how fertility treatments influenced the rate of development.

- On the B field, verdure approximately doubled between the first and second year. Between the second and third years, it increased on average by a factor of 1.27 in plots without organofertilizer, and by 0.97 (no change) on plots with 3 lbs organofertilizer-N. The average verdure in 1994 was 416 g m^{-2} in plots without organofertilizer, and 445 g m^{-2} in plots with organofertilizer.

- On the B field, the verdure of NPK fertilized plots was low in the second year compared to all other treatments, but reached a value similar to that for Cn main plots in the third year.

- On the F field, verdure did not increase substantially between the first and second year. Between the second and third year, it increased on OF3 plots to values similar to those on the B field. It also increased on the OF0 plots, but much less so than on the OF3 plots.

These results suggest that on the B field, verdure reached near maximum values in one year at the OF3 level, and in two years at the OF0 level. The F field lagged behind the B field; the OF3 plots reached verdure values similar to those for the B field in two years (by 1994), however without organofertilizer, verdure did not reach equivalent values.

Fertility effects on seedling biomass and verdure: 1992

- At the seedling stage (June 29, 1992), NPK fertilized plots had the highest biomass (Fig. A2b). The organofertilizers had little effect except at the OF3 level on the F field (Fig. A2a).

- On the B field, seedling biomass was lower on Cp than on the Cn main plots (Fig. A2a) and the difference was most pronounced at the lower levels of organofertilizer (Fig. A2b). Brewery Waste did not increase or decrease seedling biomass compared to the Cn treatment.

- On the F field, overall, the Cn main plot had higher seedling biomass than Cp or BW main plots.

- In August, there was still a trend of lower biomass (verdure) in Cp main plots compared to Cn main plots on the B field (Fig. A3a) and there was very little effect if any of organofertilizer at the OF2 level on verdure compared to OF0 (Fig. A3b). On the F field there was little effect of either main plot or subplot treatments on verdure.

These results are suggestive of some immobilization of N or phytotoxicity due to compost on the Cp main plots on the B field. Similarly, chlorophyll and student ranked greenness of the Cp main plots were low on the B field (Section III.1B).

Fertility effects on verdure: 1993

There were significant amounts of clover on the B field in 1993. Because we were evaluating fertilizing value of the soil amendments, particularly with reference to N, verdure samples were taken only at points that were at least 25 cm from the nearest clover plants.

- On the B field, organofertilizers increased verdure with the largest increase occurring between the OF1 and OF2 levels (Fig. A4a). There was a trend for Cp0 and BW0 verdure to be greater than Cn0 verdure (main plot effect; p=0.152); the difference was much weaker between Cp3, BW3, and Cn3 (main plot effect; p=0.545). There were similar trends on the F field, but they were numerically weaker and were not statistically significant. Biomass was much lower on the F field than on the B field.

- Roughly, Cp0 and BW0 produced verdure between the values for Cn1 and Cn2 for the B field, and equivalent to Cn1 on the F field (i.e. Cp and BW incorporated in 1992 had a fertilizing effect equivalent to 1-2 lbs N on the B field and 1 lb N on the F field).

- Subplot "2D" in Fig. A4a refers to plots that received a dormant application (Nov. 6, 1992) of organofertilizer in the fall of 1992 (versus September 8 for other plots). On both fields, the OF2D values were numerically higher than the OF2 values.

- Subplot "3L" refers to OF3 plots that received their mid-summer organofertilizer on August 23 (versus July 6 for the regular application). The OF3L plots were numerically lower than the OF3 values. The difference was significant for the F field, but the absolute difference was small.

- On the B field, verdure of the NPK main plot (fertilized at 3 lbs N per annum) was much lower than that of Cn3 plots, and was equivalent to that the Cn1 plots. On the F field, the NPK verdure was equivalent to that of Cn3 plots.

Fertility effects on verdure: 1994

Samples were again taken from clover-free regions of the subplots. We also took samples from grass plus clover areas so that we could examine the effects of clover on verdure. In the bar graph (Fig. A5), there are two bars for each treatment, one giving the verdure value in the presence of clover and one in its absence. Some caution is required in interpreting differences between grass only and grass plus clover areas, as the grass only areas could have had clover the previous year. Thus they do not necessarily indicate values that would have been seen in the complete absence of clover over the three seasons.

- On the B field, overall, verdure values for minus and plus clover regions showed the same trends of response to fertility treatments. Overall there were only small increases in verdure with increasing organofertilizer, and the trend was significant only for grass+clover on the Cp main plot (Fig. A5c). There was little difference between main plot treatments; Cp differed the most from the Cn main plot. On average, verdure in grass plus clover areas (490 g m^{-2}) was greater than that in minus clover areas (457 g m^{-2}), but the difference was not statistically significant (p=0.631).

- On the F field, there was a response to organofertilizer, but as on the B field, there were not large differences between main plot treatments. In contrast to the B field, verdure was higher on the minus clover plots (556 g m^{-2}) than on the plus clover plots (434 g m^2) overall, and the difference was highly significant (p=0.012).

- Subplot "1b" in Fig A5 refers to OF1 subplots that were bag-mowed beginning on July 17, 1993. On the B field, the bag mowed plots had lower verdure than OF1 mulch mowed plots (not significant), while on the F field, the bag mowed plots had higher verdure (not significant).

- Subplot "3X" refers to OF3 subplots that did not receive fertilizer in 1994 (i.e. no spring or mid-summer applications as on the OF3 subplots). OF3X verdure values were not reduced on the B field compared to OF3, but they were significantly reduced on the F field (Fig. A5a).

- On the B field, a clover-free region could be found on only one of the nine quadrats placed in NPK main plots. Its verdure (265 g m^{-2}) was very low compared to other treatments, however the plus clover values (all main plots) were similar to those of other treatments (Fig. A5c).

- On the F field, the minus clover NPK verdure was equivalent to that of Cn2 plots, but was below that of the Cn3 plots. There was no clover in the sampled areas on the F field (Fig. A5d).

- Tiller density was determined for selected treatments (Table A1). Of the five treatments sampled, NPK tillers had the smallest average weight per tiller. It was noted in the field that there was a generally finer texture on the NPK plots.

The 1993/94 verdure results suggest that the inhibitory effects of the compost in the Cp main plots on the B field had been relieved by 1993. Low verdure values for NPK main plots on the B field suggest some negative response to synthetic fertilizer, however this was not apparent in 1994. By 1994, there was little effect of main plot treatments on verdure. The results also indicate significant differences between the B and F fields in terms of mulch vs. bag mowing, and the absence or presence of clover.

Clippings

Clipping yields were measured in 1993 and 1994. These data are more of a snapshot nature than the verdure or base verdure values, i.e. they reflect the particular mid-summer conditions much more strongly than would the verdure values. Interesting trends in these data were the following:

1993 (sampled July 13)

- On the B field, there was significant stimulation of clipping production measured on July 13 by fertilizer applied to OF3 plots on July 6, and the values were much higher than those for NPK plots which also received mid-summer fertilization (Fig. A6a).

- On the B field, there was still an effect of the previous fall dormant organofertilizer treatment (Fig. A6a)

- On the F field, clipping yield was very reduced on the NPK main plots, while on the equivalent, OF3 plots, clipping yields were increased.

1994 (sampled August 10 &11)

- Clipping yields in the 1994 sampling were two or three times those on July 6, 1993. It was noted by maintenance personnel that the B field "came on strong" in 1994.

- There was roughly equivalent clipping production in minus and plus clover areas except on the F field Cn main plot in which clipping yield was much higher for plus clover than for minus clover samples. Verdure was lower in the plus clover samples (above); presumably the higher clipping yield is related to the plus clover areas being less drought susceptible than the minus clover areas.

- Exceptionally high clipping production was documented on the NPK (minus clover) main plot on the B field but not on the F field (mid-summer fertilizer was applied July 1).

Relationship of clippings to verdure

The quantity of clippings are a function of verdure and of the photosynthetic activity per unit of the verdure over the period immediately preceding harvest of clippings. During periods of little water stress, we would expect to find a strong correlation between clippings and verdure. In periods of high water stress, this relationship could be influenced by differences in soil properties which affect water absorption and retention, and by differences in withdrawal of water (i.e. often slower growing plants will suffer less water stress because they do not deplete the soil water as quickly as faster growing plants). R^2 values for regressions of clipping yields on verdure for different Blocks and main plot treatments are given in Table A2. The R^2 values provide a measure of how strongly variation in clipping yield is related to variation in verdure (i.e. +1: completely; 0: none; -1: completely negative effect). Some examples of the relationships are given in Fig. A7.

Following, we summarize interesting points in these data and consider whether differences can be reasonably explained by assuming that the less water limited a system is, the higher will be the correlation between clipping yield and verdure.

- Overall, R^2 values for the 1993 samples are much higher (and more are statistically significant) than those for the 1994 samples and all of the 1993 relationships are positive ones versus some negative relationships between clippings and verdure in 1994 (Table A2).

These observations suggest there was less water stress preceding the July 13, 1993 sampling than preceding the Aug. 10 1994 sampling. This interpretation is supported by precipitation data (see total weekly precipitation levels in Section VII- Appendix 1); in the 28 days preceding the July 13, 1993 sampling, rainfall totaled 80.7 mm, while in the 28 days preceding the August 10, 1994 sampling, rainfall totaled only 36.9 mm. Furthermore, we irrigated when there was dry weather in 1993 because we had to conduct a lot of overseeding, while in 1994, we did not irrigate. Also, clipping yields were much higher in 1994, which could have contributed to faster lowering of soil water and onset of water stress.

- In 1993, the regression for Block 4 (F field) had the lowest R^2 value, i.e. the F field appeared to experience the highest degree of water limitation, which is what would be expected on the basis of soil physical data. Greater drought stress was evident also from the mid-summer browning which occurred on the F field but not on the B field.

- In 1993 and 1994, the R^2 values for the B field were highest for BW main plots, compared with Cn and Cp main plots. In 1994, only the BW main plots exhibited a positive relationship between clippings and verdure (Table A2).

These differences are not explained by differences in verdure, e.g. if there was a much lower verdure on BW plots, it might result in less water stress. They seem to suggest that BW improved the water status of the turf compared to Cn and Cp treatments. Data are more limited for the F field, but in both years, BW had higher R^2 values than the Cn treatment, suggesting improved water status at the time of sampling.

- Regressions do not differ significantly for plus clover and minus clover data in 1994 (Fig. A7). However, it is interesting to note that the highest clipping values at higher verdure levels are all for the plus clover samples.

Overall, these results suggest that factors other than verdure (i.e. water stress), can significantly influence clipping production. Higher R^2 value for BW compared to Cp main plots could be due to the hydrophobic nature of the compost, and its resistance to wetting once dried.

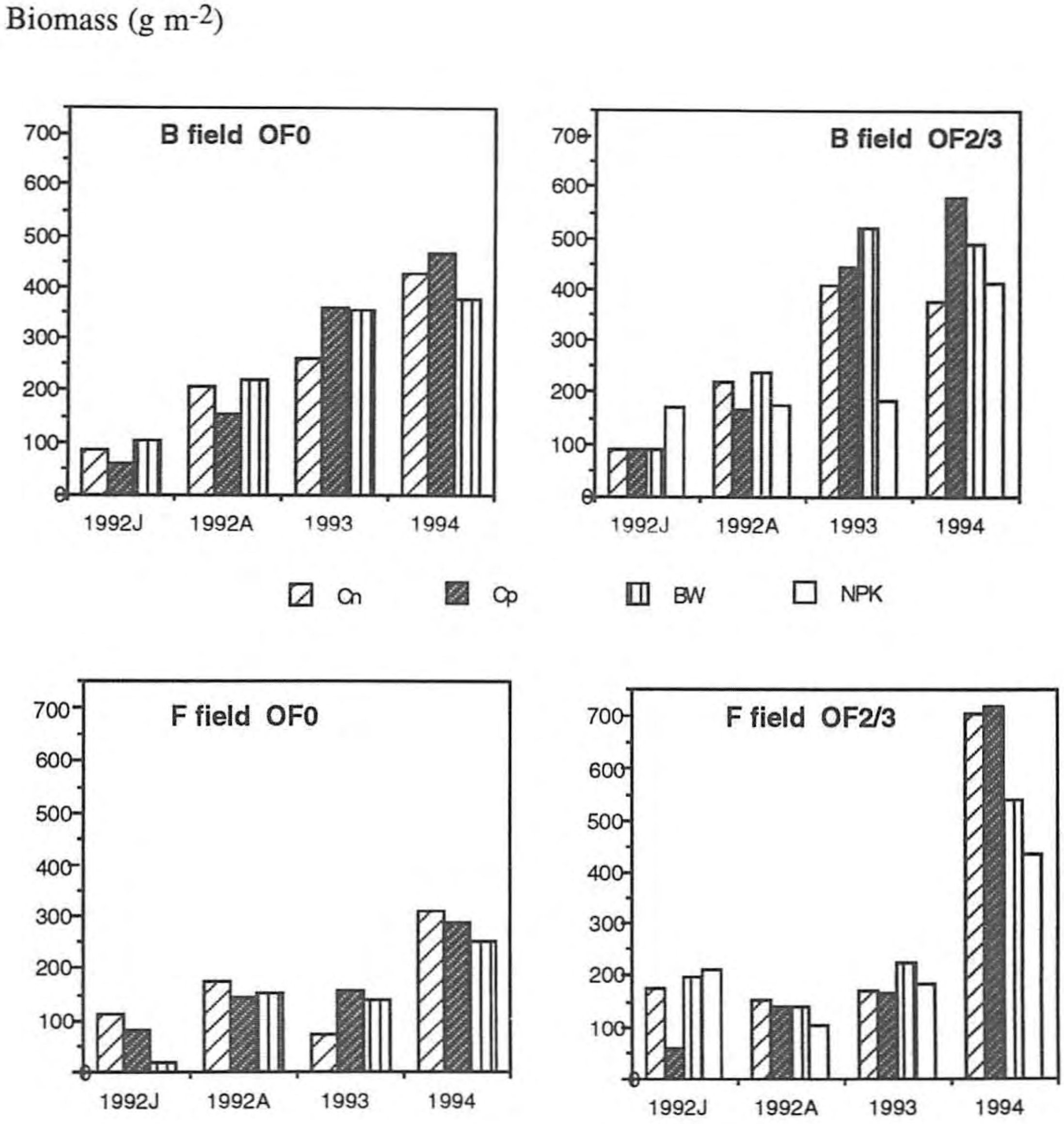


Figure A1. Seedling biomass and verdure over three seasons. 1992J refers to June 29, 1992 (seedling biomass), 1992A to verdure on August 19, 1992. 1993 and 1994 samples were taken July 13 and August 10-11 respectively. Different bar types give values for the different main plot treatments at the indicated levels of organofertilizer. NPK received 3 lb N per annum. At the OF2/3 level, values are for organofertilizer applied at 3 lb N level except for the 1992 August data which refer to organofertilizer at 2 lb N level.

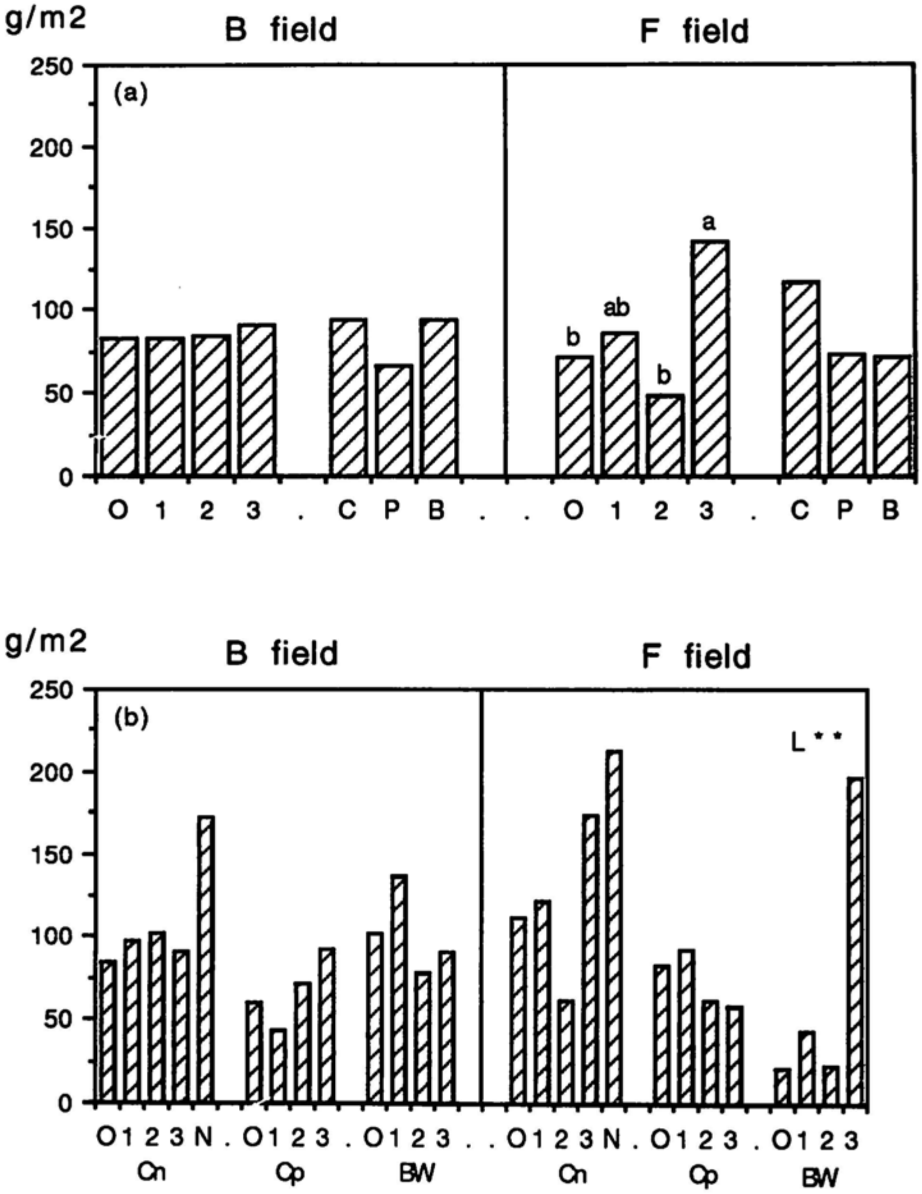


Figure A2. Seedling biomass on June 29, 1992.

__B Field ANOVA (Split plot)__
MP F (2,4): 0.480, p=0.650
MP * Sp (6,54): 0.946, p=0.471
cv MP = 129%

Sp F (3,54): 0.169, p=0.917
cv Sp, MP * Sp = 50%

__F Field ANOVA (RCB)__
Sp F (3,18): 3.11, p=0.052
cv Sp = 64%

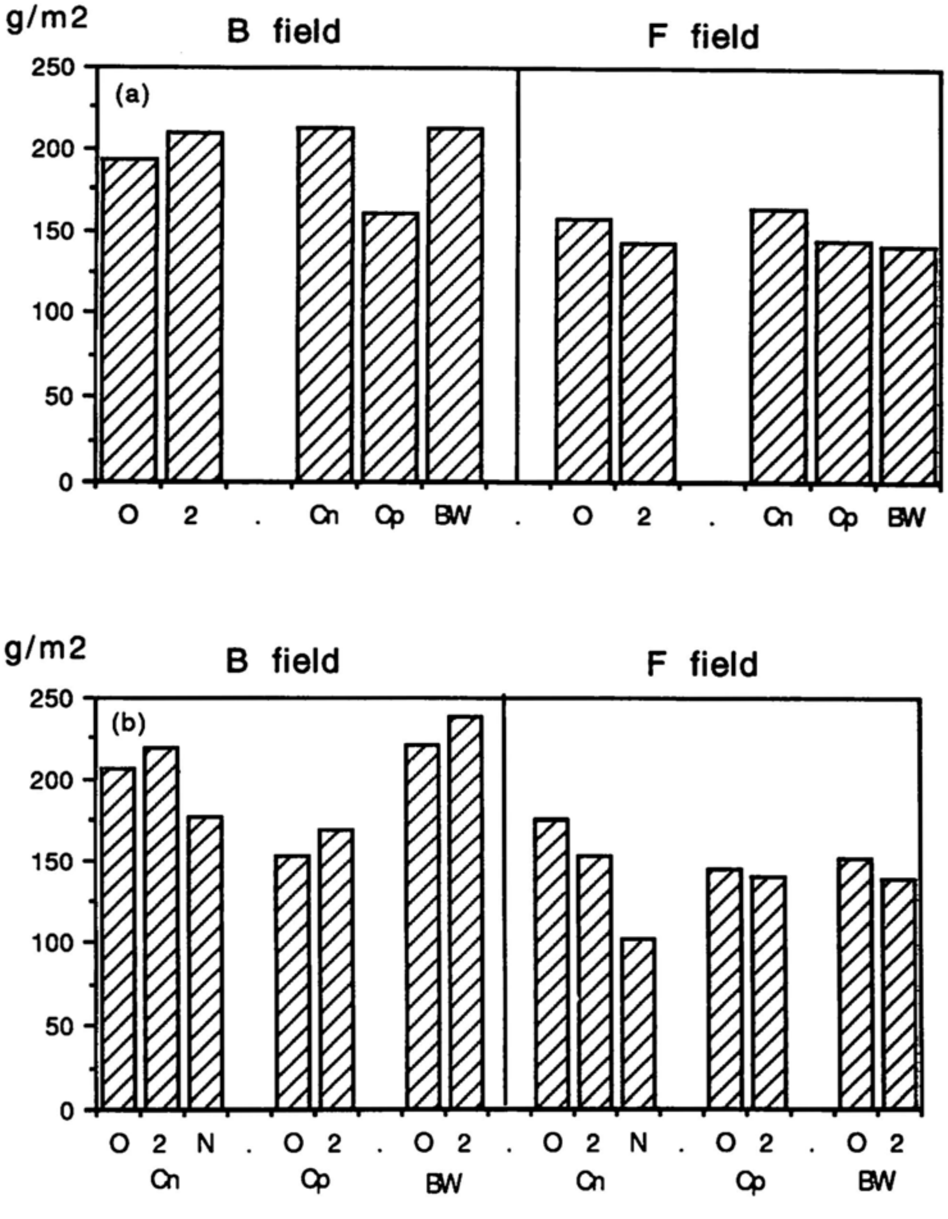


Figure A3. Verdure on August 20, 1992.

B Field ANOVA (Split plot)

MP F (2,4): 3.40, p=0.137
MP * Sp F (2,24): 0.027, p=0.973
cv MP = 34%
Sp F (1,24): 2.73, p=0.111
cv Sp, MP * Sp = 14%

F Field ANOVA (RCB)

Sp F (1,8): 3.60, p=0.095
cv Sp = 8.5%

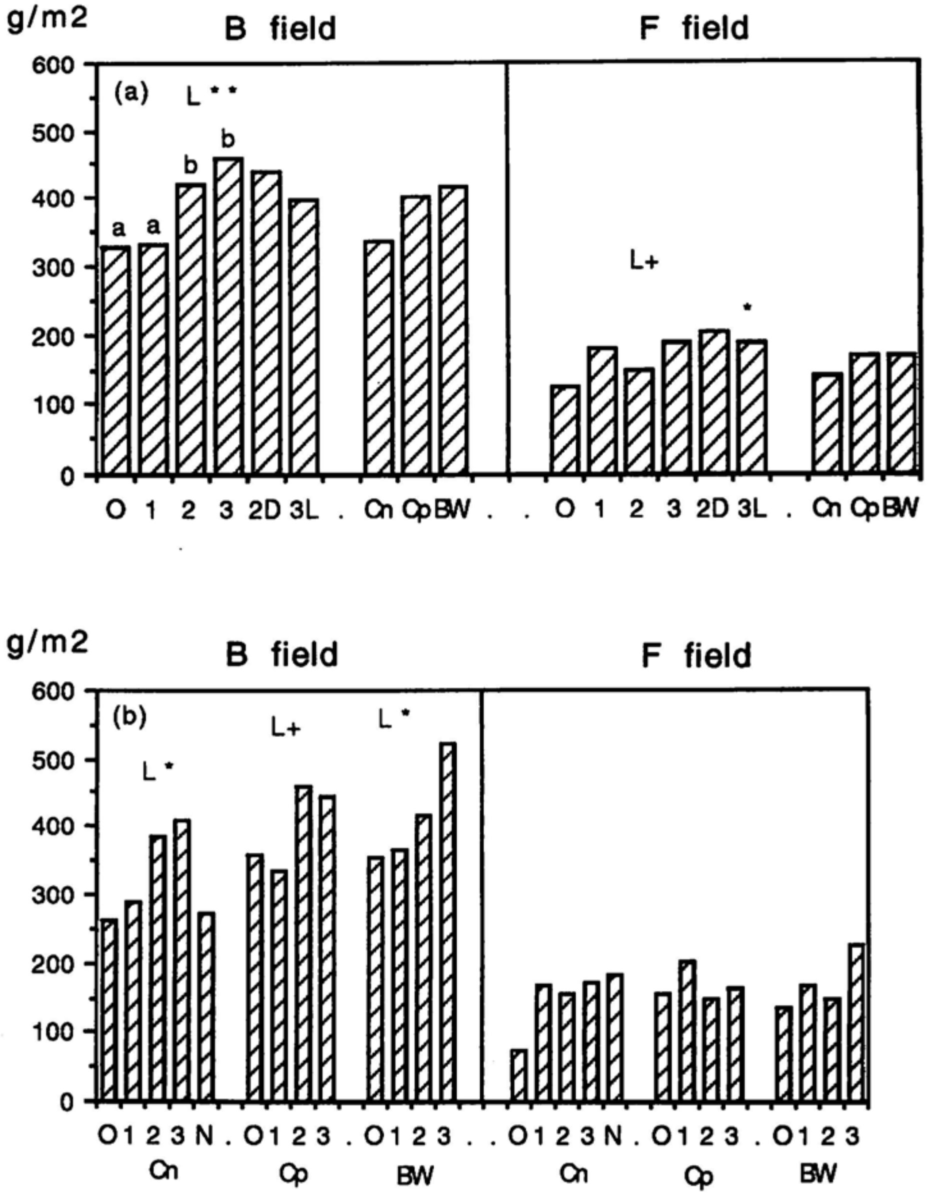


Figure A4. Verdure on July 13, 1993.

B Field ANOVA (Split plot)

MP F (2,4): 1.46, p=0.333
MP * Sp F (6,18): 0.639, p=0.697
cv MP = 42%

Sp F (3,18): 10.9, p=0.0003
cv Sp, MP * Sp = 17%

F Field ANOVA (RCB)

Sp F (3,6): 3.12, p=0.109
cv Sp = 44%

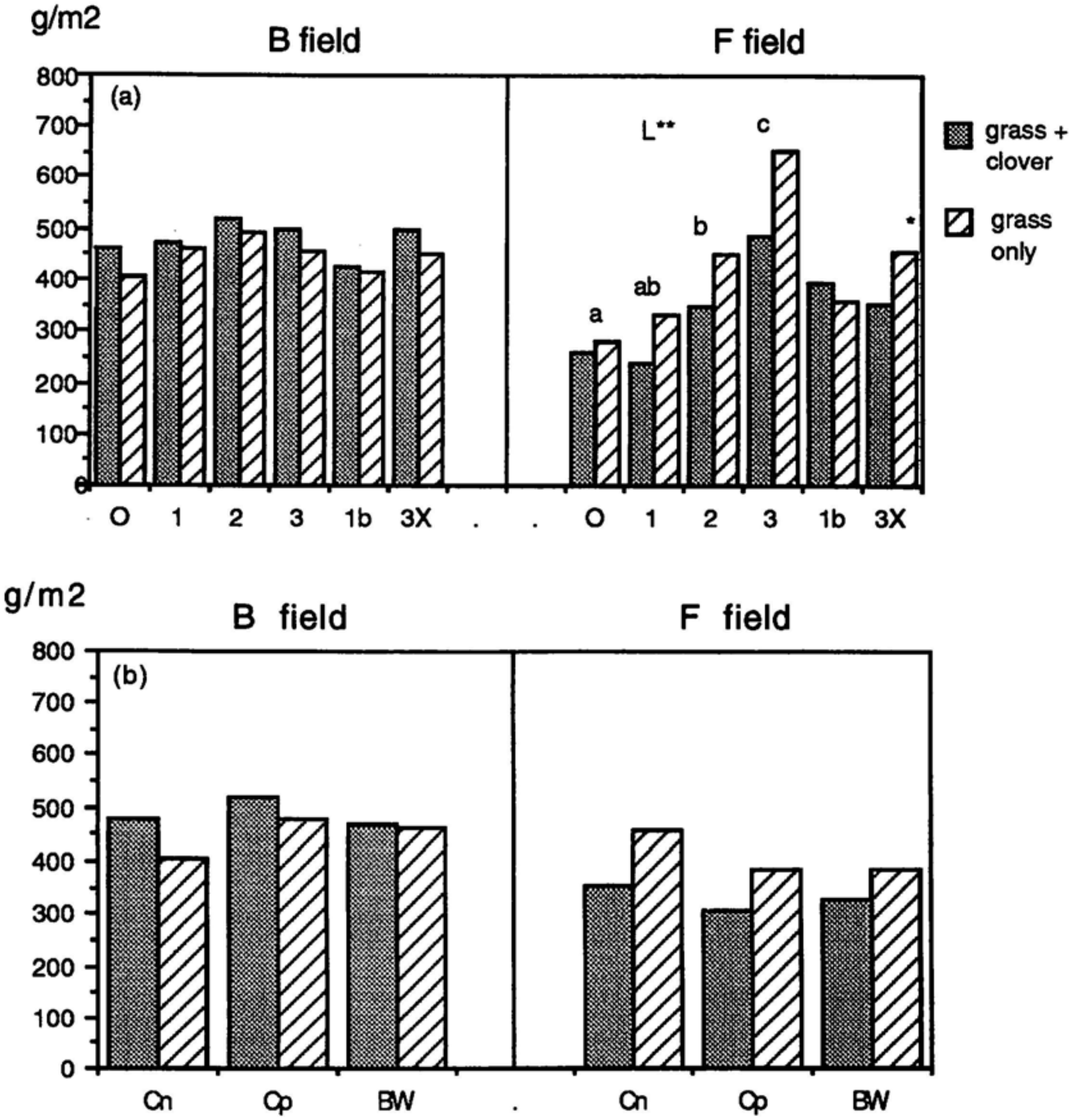


Figure A5. Verdure on August 10-11, 1994, for all main plots combined (a), and all subplots combined (b).

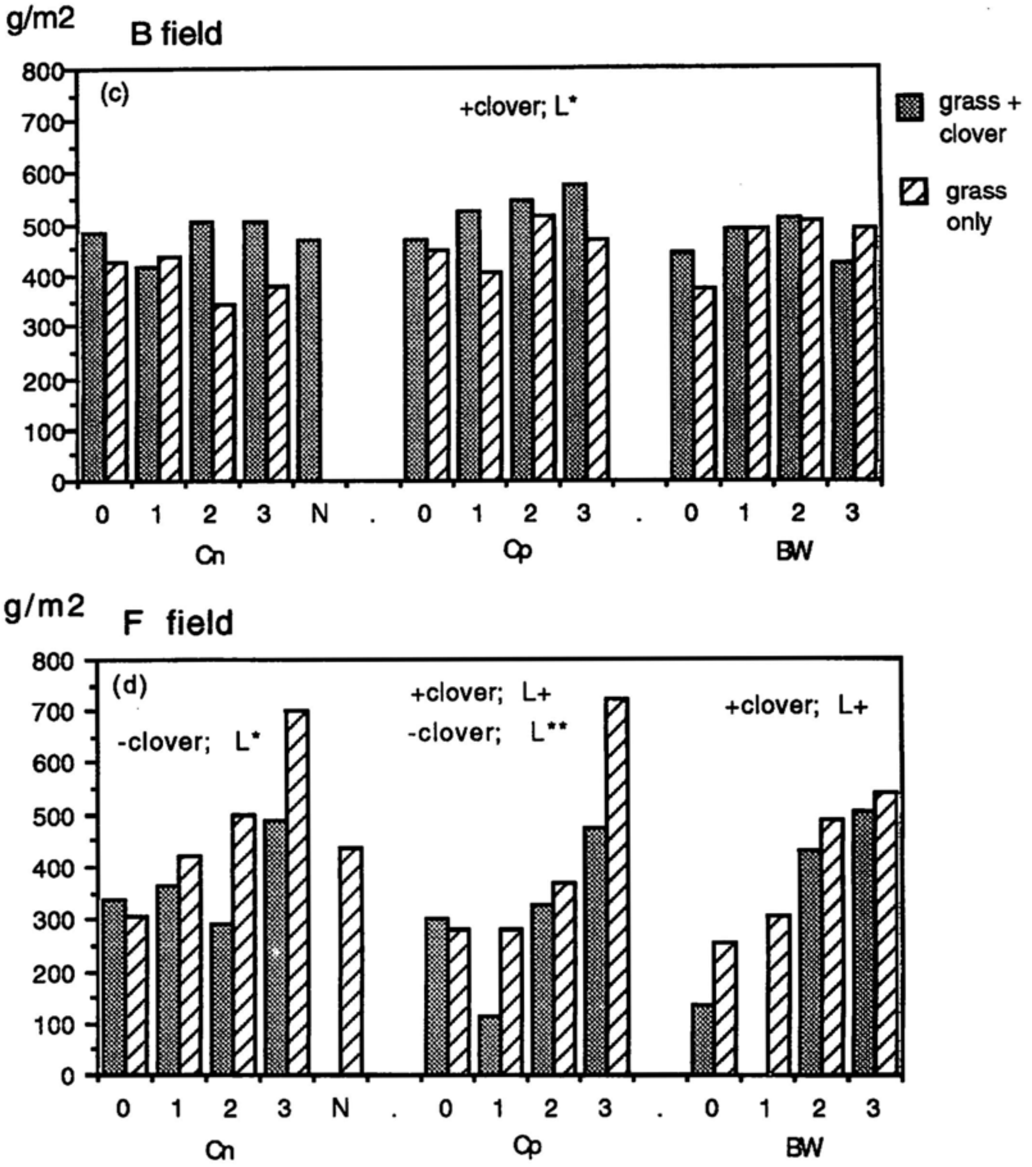


Figure A5 (Concluded). Verdure on August 10-11, 1994, for individual main plots and subplots for the B (c) and F (d) fields.

B Field ANOVA (Split-split plot)

MP F (2,6): 0.005, p=0.9953
Clover F (1,33): 0.235, p=0.632
MP * Sp F (2,4): 0.279, p=0.940
cv MP = 65.8%
cv Sp, MP*Sp = 43%

Sp F (3,6): 1.25, p=0.3127
MP*Clover F (2,33): 0.961, p=0.393
MP*Sp*Clover F (6,33): 0.960, p=0.467
cv Clover, MP*Clover, MP*Sp*Clover =15%

F Field ANOVA (Split plot)

Clover F (1,19): 11.4, p=0.003
Sp F (3,6): 9.91, p=0.010
cv Sp = 32%

Sp*Clover F (3,19): 1.27, p=0.310
cv Clover, Sp*Clover = 21%

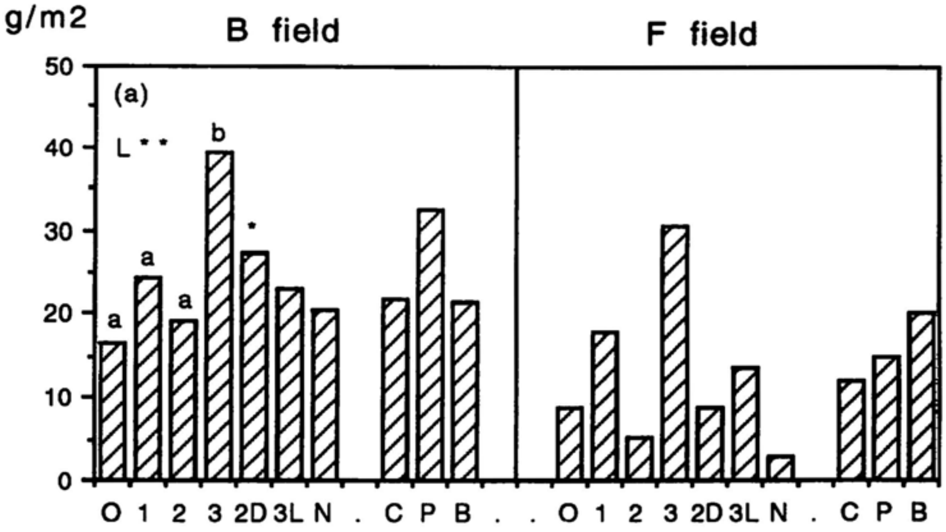


Figure A6. Clipping weight on July 13, 1993.

B Field ANOVA (Split plot)
MP F (2,4): 1.43, p=0.340
MP * Sp F (6,18): 1.82, p=0.151
cv MP = 63%

Sp F (3,18): 8.43, p=0.001
cv Sp, MP * Sp = 42%

F Field ANOVA (RCB)
Sp F (3,6): 2.79, p=0.131
cv Sp = 75%

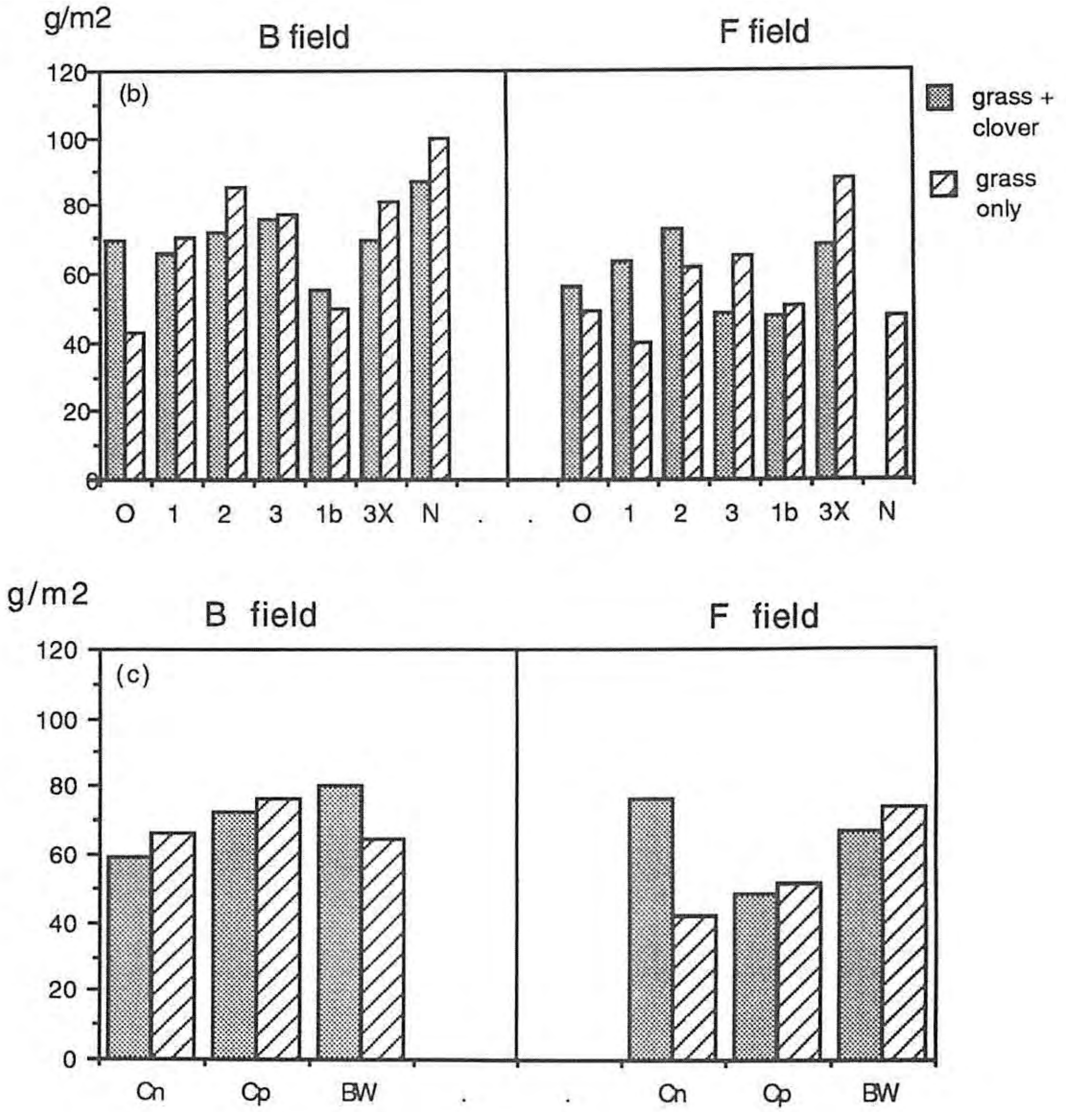


Figure A6 (Concluded). Clipping weight on August 10-11, 1994.

<u>B Field ANOVA (Split-split plot)</u>

MP F (2,4): 0.05, p=0.9516
Clover F (1,26): 1.64, p=0.211
MP * Sp F (4,6): 2.54, p=0.061
cv MP = 63.9%
cv Sp, MP*Sp = 32.2%

Sp F (3,6): 0.93, p=0.4456
MP*Clover F (2,26): 1.94, p=0.164
MP*Sp*Clover F (4,26): 1.24, p=0.316
cv Clover, MP*Clover, MP*Sp*Clover =27%

<u>F Field ANOVA (Split plot)</u>

Clover F (1,13): 0.144, p=0.710
Sp F (3,6): 0.396, p=0.761
cv Sp = 46%

Sp*Clover F (3,13): 0.761, p=0.536
cv Clover, Sp*Clover = 34%

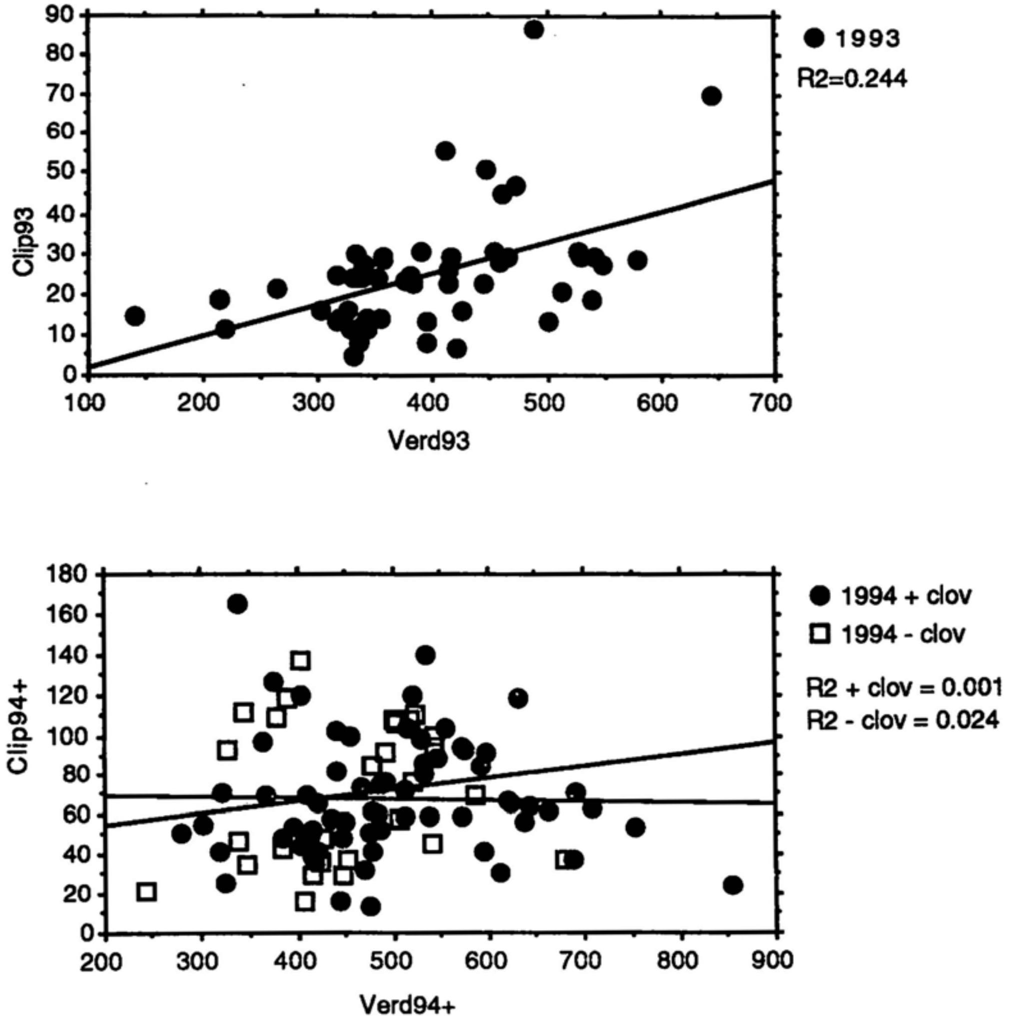


Figure A7. Regressions of one week clipping yield on verdure for the B field OF plots July 13, 1993 and August 10, 1994. Units for both are g m^{-2}. Slopes for plus and minus clover in 1994 do not differ significantly (p=0.733).

Table A1. Individual tiller weight (1 cm above soil to mowing height) and shoot density for selected treatments, August 10, 1994.

Treatment	mg/tiller		Tillers, 1000's per m^2	
	Blocks 1-3	Block 4	Blocks 1-3	Block 4
Cn0	5.73	5.171	94.5	69.4
Cn2	7.28	6.261	68.0	85.5
Cp3	8.66	5.892	66.0	122.2
BW1b	5.87	7.148	68.1	42.8
NPK	5.35	2.740	62.4	159.2
p Treatment Effect	0.137	0.822	-	-

Table A2. Statistics for linear regressions of clipping yield on verdure.

Data Set	Deg. Freedom		F	p	R^2	Slope
	Model	Error				
1993 Block 1	1	16	10.92	0.0045	0.4057	+
Block 2	1	16	4.12	0.0593	0.2048	+
Block 3	1	16	3.24	0.0907	0.1684	+
Block 4	1	16	3.05	0.0997	0.1603	+
Cn 1-3	1	16	7.41	0.0151	0.3164	+
Cp 1-3	1	16	4.11	0.0596	0.2044	+
BW 1-3	1	16	12.62	0.0027	0.4409	+
Cn 4	1	4	0.19	0.6800	0.0471	+
Cp 4	1	4	0.11	0.3510	0.2170	+
BW 4	1	4	0.99	0.3740	0.2000	+
1994 Block 1	1	35	0.09	0.7670	0.0025	-
Block 2	1	31	9.27	0.0050	0.2300	-
Block 3	1	25	0.72	0.4050	0.0278	+
block 4	1	10	0.33	0.5790	0.0319	+
Cn 1-3	1	26	1.10	0.3040	0.0037	-
Cp 1-3	1	31	1.04	0.3160	0.0324	-
BW 1-3	1	34	3.58	0.0671	0.0952	+
Cn 4	1	10	0.26	0.6200	0.0255	+
Cp 4	1	14	0.49	0.4960	0.0337	-
BW 4	1	10	0.33	0.5790	0.0319	+

B. Greenness

Greenness of turf is an important quality variable in the turf industry. Greenness or "color" is commonly rated by specialists on a scale of 0 to 9 with 9 the darkest green possible (Skogley and Sawyer, 1992). Such a system would have been difficult to apply at The Oaks where numerous plots had to be observed many times and by different personnel.

In the first field season, we attempted to use a chlorophyll meter as a completely objective method for documenting differences in greenness between fertility treatments. This method proved to have serious technical limitations[1]. However, there were visually obvious differences in greenness (see photos), and a trial of a ranking method by 19 students produced results similar to those obtained with a chlorophyll meter (compare chlorophyll values on July 16 and August 19 with rating on July 31, Fig. B1). Thus, beginning in the fall of 1992, greenness of main plots and subplots was monitored by ranking methods. These were applied to main plots within each Block, or to organofertilizer subplots within each main plot.

Rank values indicate how main plots compare to each other, or how different subplot treatments within each main plot type compare to each other, however they do not indicate absolute values of greenness. Chlorophyll measurements were made on particular occasions in order to provide values that could be compared between the B and F fields. Neither the rank or chlorophyll values, however, indicate how the color rates in relation to industry standards. In 1992, and for most of 1993 and 1994, darker green plots on the B and F fields were considered by Edmonds personnel to be equivalent to the highest quality, commercially maintained turfs. Ratings by industry personnel other than Edmonds (see Section VII-Appendix 2B) also indicate that the higher ratings correspond to commercially desirable levels of greenness.

Photos 4, 5, and 6 illustrate, visually, some of the differences in greenness discussed in this section.

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[1] Difficulties with use of chlorophyll meter included: (i) it could be used only with larger leaves, thus there would be some species bias in the measurements, (ii) it was too time consuming to apply to subplots - a full set of measurements of five leaves per plot took more than one day, and it appeared that more leaves had to be measured to pick up smaller differences that could be discriminated visually, (iii) in the spring of 1993, much higher values were obtained for grass that had not started growing than for grass which had started to grow and appeared darker green. This was probably due to differences in thickness (Campbell, et. al., 1990), the non-growing leaves being thicker than those which had started growing. Differences in leaf thickness between treatments could be a factor complicating the use of the technique in other comparisons.

Methods

Ranking of greenness was conducted separately for each set of main plots in each Block (ranking 1 low to 4 high); and for each set of organofertilizer subplots in each main plot (ranking 1 low to 8 high). The latter was done without reference to subplot treatments. In the case of main plots, the sequence of treatments was usually known to observers. They were instructed to give plots different ranks only if they did not have to deliberate on the ranking. In most cases, the rankings were conducted by two observers independently. After their values were recorded they compared notes and if two plots had different rankings, they were given one value. These rankings were for overall plot greenness, but we attempted to exclude diseased leaves from the evaluation. Whenever possible, rankings were conducted on cloudy days or early in the day in order to minimize reflectance problems.

Chlorophyll readings were made with a Minolta SPAD-502 chlorophyll meter on individual leaves at approximately mid-length. Reported units are "SPAD units". All observations were conducted with one meter, thus the values can be compared between different dates.

The Friedman (non-parametric) Test was applied to ranking data. A low p-value indicates a high degree of concurrence of rank orders between Blocks 1-3 (B field) for main plot data, or concurrence between rank orders for subplots compared for each of the Cn, Cp and BW main plots separately (B field) or all together as indicated. A high p value indicates either lack of differences in ranking (e.g., if there is little difference in color), or lack of consistency between Blocks in rank orders.

Differences between fields

- Comparable sets of chlorophyll values for main plots (on OF0 subplots) were obtained in mid-summer of each year (Fig. B2). These data show that in 1992, F field values (Block 4) were similar to those of the B field (Blocks 1-3) overall, while in 1993 and 1994, they were consistently lower. This was also the visual impression, i.e. that the fields had equivalent greenness in 1992, while in 1993 and most of 1994, the B field was darker green than the F field.

- Measurements on subplots (Table B1) showed that the chlorophyll values for the darkest organofertilizer plots overlapped over most of the ranges for both fields in 1992. In 1993 and 1994, the higher organofertilizer chlorophyll values on the F field overlapped with lower values on the B field.

- In October and later in the fall of 1994, the F field was observed to darken up considerably and to approach B field greenness. This was reflected in high chlorophyll SPAD values for the F field even at the OF0 level (Table B2).

Fertility effects on greenness

1992

- From June though August, 1992, the most striking differences in color were associated with main plot treatments. At the seedling stage, (June 29), grass on the two fields had similar chlorophyll values and responded positively to brewery waste and NPK (Fig. B1a). Grass on the F field, but not on the B field, responded positively to compost.

- After June, main plot fertility effects on greenness differed between the two fields (Fig. B1c). On the B field, BW main plots stood out by their dark green coloration, and Cp main plots by their being light green compared to Cn (Photo 4d). On the F field, the Cn main plot was darker green than other main plots.

- One set of chlorophyll measurements in July on the B field, Block 3 (Fig. B1e) illustrates that chlorophyll values did not increase with increasing level of organofertilizer. A set of measurements made on August 19 illustrated some stimulation of greenness by organofertilizer (Fig. B1f).

- After the fall fertilization on Sept. 8, 1992 (top dressings of organofertilizer applied to OF1,2,3 subplots, and of NPK to the NPK main plot), organofertilizer treatments began to be more readily distinguishable as distinct plots (Fig. B3) and on the F field, the NPK main plot became much darker than other main plots (outside of the organofertilizer plots) (Fig. B4). Organofertilizer had more of a stimulating effect on the B field than on the F field with the OF3 subplot showing maximum greenness on the B field and OF1 subplot on the F field.

- The OF2 plots that were fertilized on November 6 rather than September 6 (referred to as OF2D) were ranked darker green than OF0 plots on Oct. 6, indicating some carryover effect from the spring fertilization (OF2 plots received fertilizer just before seeding, but not subsequently until Sept. 6).

1993

- In the spring of 1993, the dormant fertilized OF2D plots were the earliest greening of the OF plots on both fields (Fig. B3). The dormant fed plots also exhibited the most initial growth and had the least winter injury (Section III.1D).

- There was a definite response of greenness to spring fertilization (conducted on May 18; see June 11, 1993 chart, Fig B3). In July and August, this effect had largely dissipated on the B field, but was still evident on the F field (Fig. B3, Photos 5a,b). In the fall (before the dormant fertilizer application on Nov.17), there was some stimulation of greening at the OF3 level on the B field, but the effects were stronger on the F field.

- The effects of main plot treatments on the B field in 1993 were statistically less significant than the effects of subplot treatments (compare probability values for main plots in 1993 (Fig. B4) with values for organofertilizer plots within different main plots, (Fig. B3)), suggesting that subplot effects were stronger than the main plot effects. This was visually apparent, and was a change from 1992 when main plot effects were stronger (July) or roughly equivalent (fall) to subplot effects on greening.

- In 1993, on the F field, the NPK main plot had the highest rankings throughout the season while on the B field the NPK plots were darkest and most different from others only for a few weeks after the spring and mid-summer fertilization. Early in the season, BW main plots had relatively high rank values, however, towards the end of the season these declined while those of Cp main plots went up (Fig. B4).

1994

- In 1994, there was a strong effect of organofertilizer on greening at the first sampling on April 28 on both fields (Fig. B5).

- By May 13, all plots had achieved similar greenness on the B field, while on the F field there remained a strong organofertilizer effect on greenness. In June through August, there were transient effects of organofertilizers on the B field, but sustained and striking effects on the F field (Photos 6a,b).

- In the fall, the F field exhibited much less consistency in response of plots to organofertilizer. As noted above, the F field overall became much darker in the fall of 1994 and closer to the B field in greenness (Table B2, Photos 6c,d).

- Main plot effects were not strong on the B field in 1994. Compost plots stood out most overall, followed by NPK. By the end of the season, BW plots began to appear lighter green than Cn plots. On the F field, NPK was darkest green on most dates (Fig. B6).

Interpretation

Greenness values generally reflect N concentrations more strongly than other factors (Turner and Hummel, 1992). The patterns we observed are consistent with other evidence for an initial release of N from brewery waste (summer 1992), immobilization or phytotoxic effects of compost on Cp main plots on the B field in 1992, and turnover of the potato compost during the second and third year giving higher greenness. Brewery Waste plots (in the absence of supplemental fertilizer) began to get "beat out" in 1994.

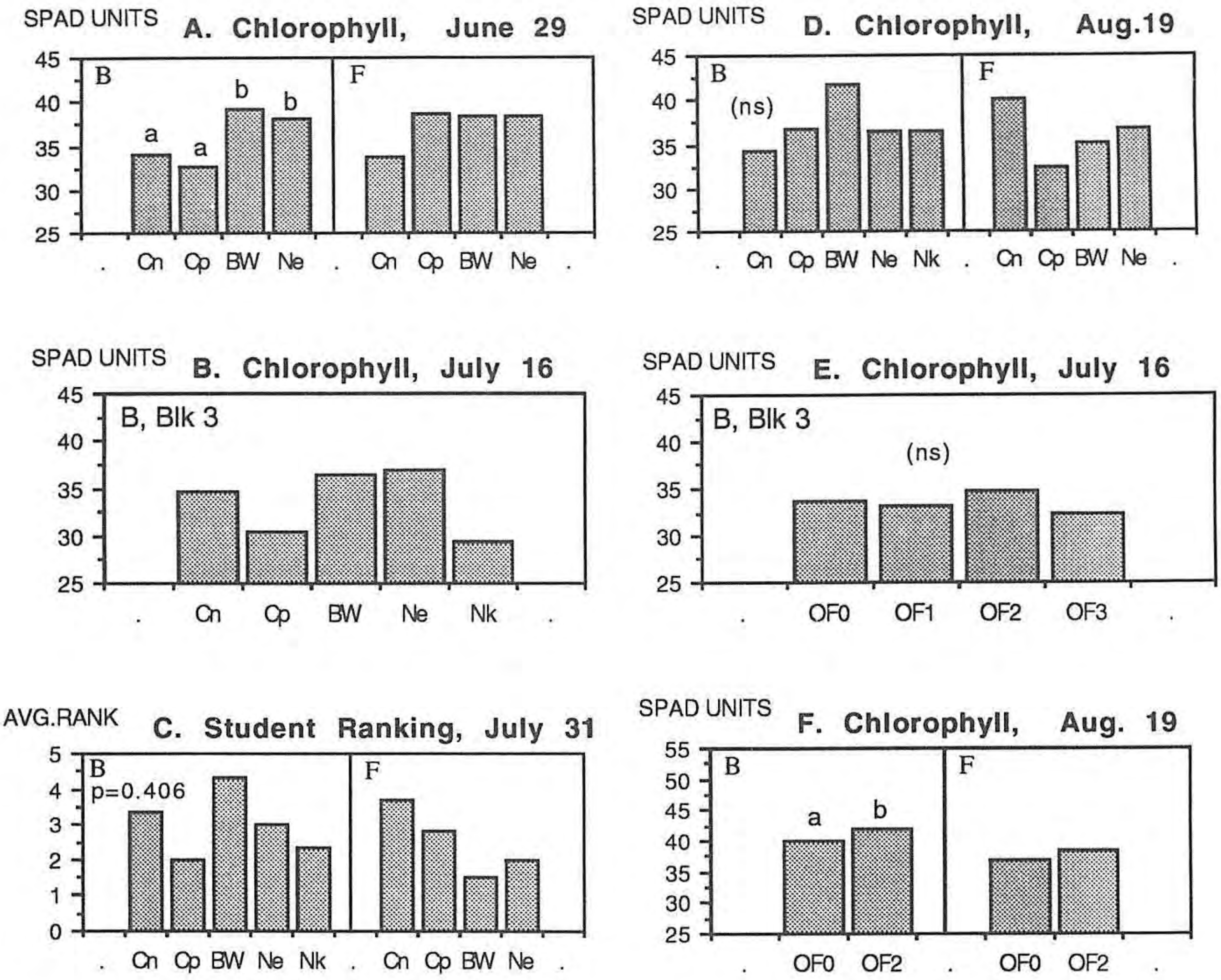


Figure B1. Chlorophyll values and student ranking of greenness of main plots (A-D) and subplots (E-F), June through August, 1992. Chlorophyll values are averages for 10 to 30+ leaves. Ranking values (July 31) are averages for 19 students who ranked relative greenness of Cn, Cp, BW main plots and NPK-Ecomix (Ne), NPK-Kentucky bluegrass (Nk) subplots (1 lowest; 5 highest). Organofertilizer values at bottom of chart are averages for OF plots in main plots. Letters above bars indicate significant differences by Fisher's Protected LSD (α=0.05); (ns) indicates that the overall F value for fertility treatment effects in the ANOVA was not significant. Where neither are present, no statistical test was applied because of lack of replicates. P-value for ranking data is from Friedman Test applied to average ranking values for each of the three Blocks on the B field; a high, non-significant p-value indicates overall poor concurrence of ranking of main plots between the three Blocks. P-values applied to 19 student rankings for each Block were all less than 0.001, indicating a high degree of concurrence between student rankings within individual Blocks.

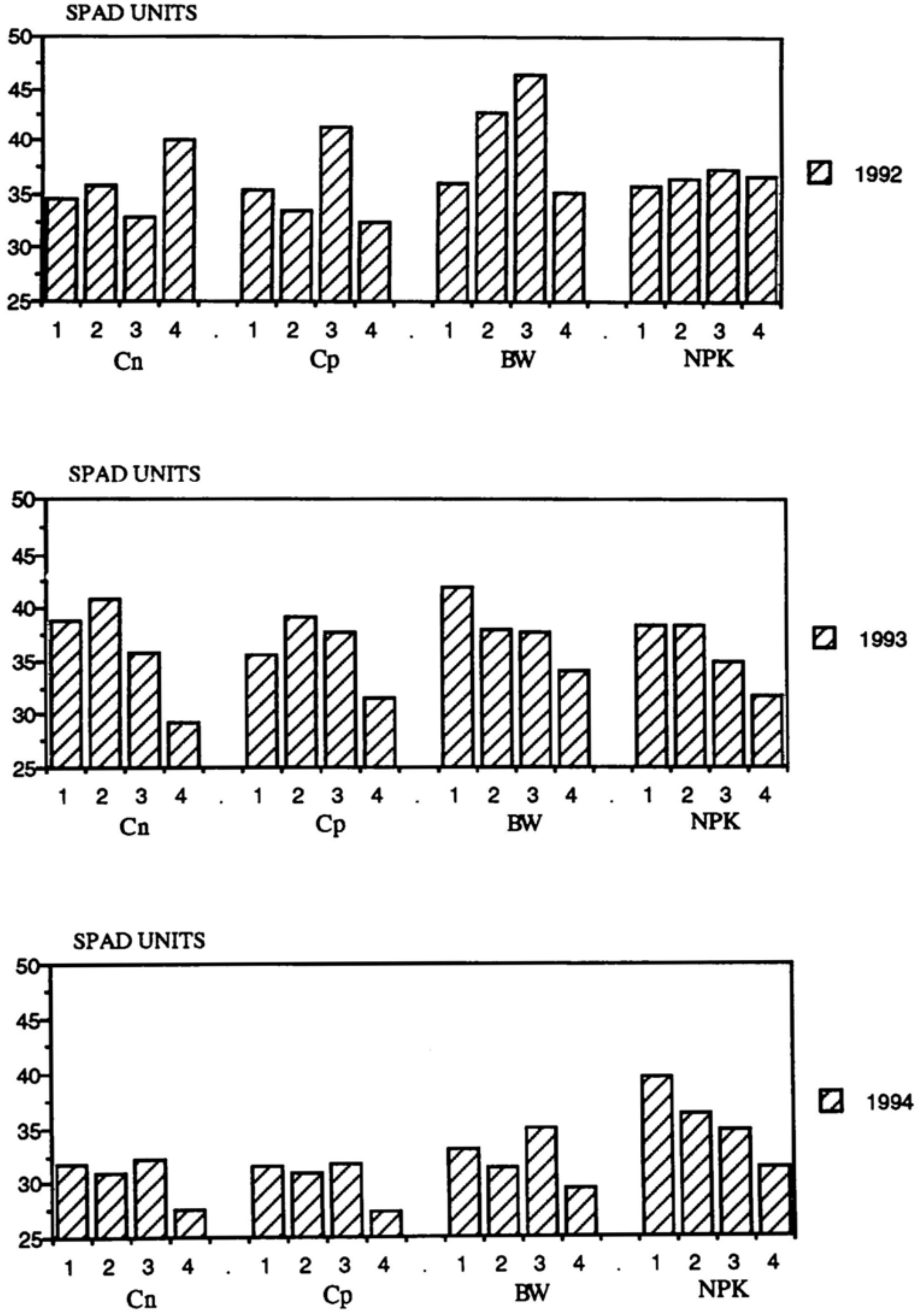
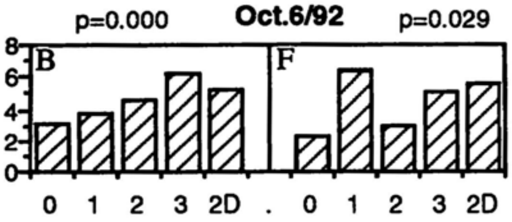


Figure B2. Main plot chlorophyll values in the four Blocks, on Aug. 19, 1992, July 7, 1993, and July 11, 1994. Values are means of 30 (B Field, Blocks 1-3) or 10 (F field, Block 4) leaves. Measurements in Cn, Cp, and BW main plots were made in the OF0 subplot (no organofertilizer).

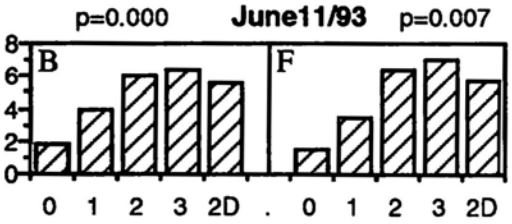
→ *Fertilizer applied on Sept.8,1992*
(except plot 2D)


Oct.6/92

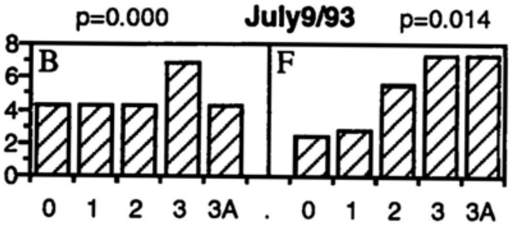
→ *Fertilizer applied to plot 2D on*
Nov.6,1992.

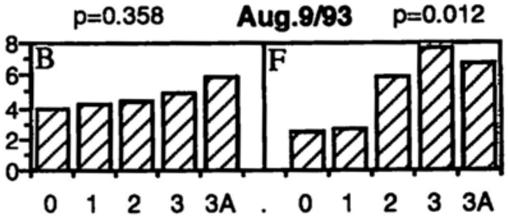

May17/93

→ *Fertilizer applied on May18,1993.*

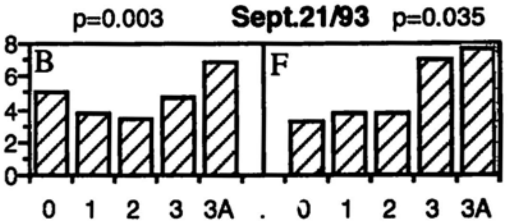

June11/93

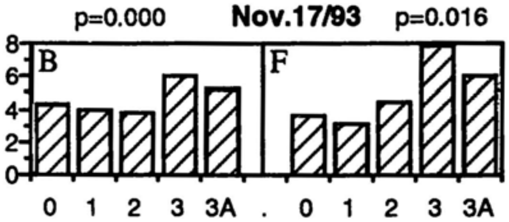
→ *Fertilizer applied to plot OF3 on*
July6,1993.


July9/93


Aug.9/93

→ *Fertilizer applied to plot 3A on*
Aug.17,1993.


Sept.21/93


Nov.17/93

→ *Fertilizer applied on Nov.17,1993.*

Figure B3. Visual greenness rankings for all subplots for 1992 and 1993. Values are averages for all Blocks and main plots (except NPK). Values for individual main plots are provided in Section VII-Appendix 3.

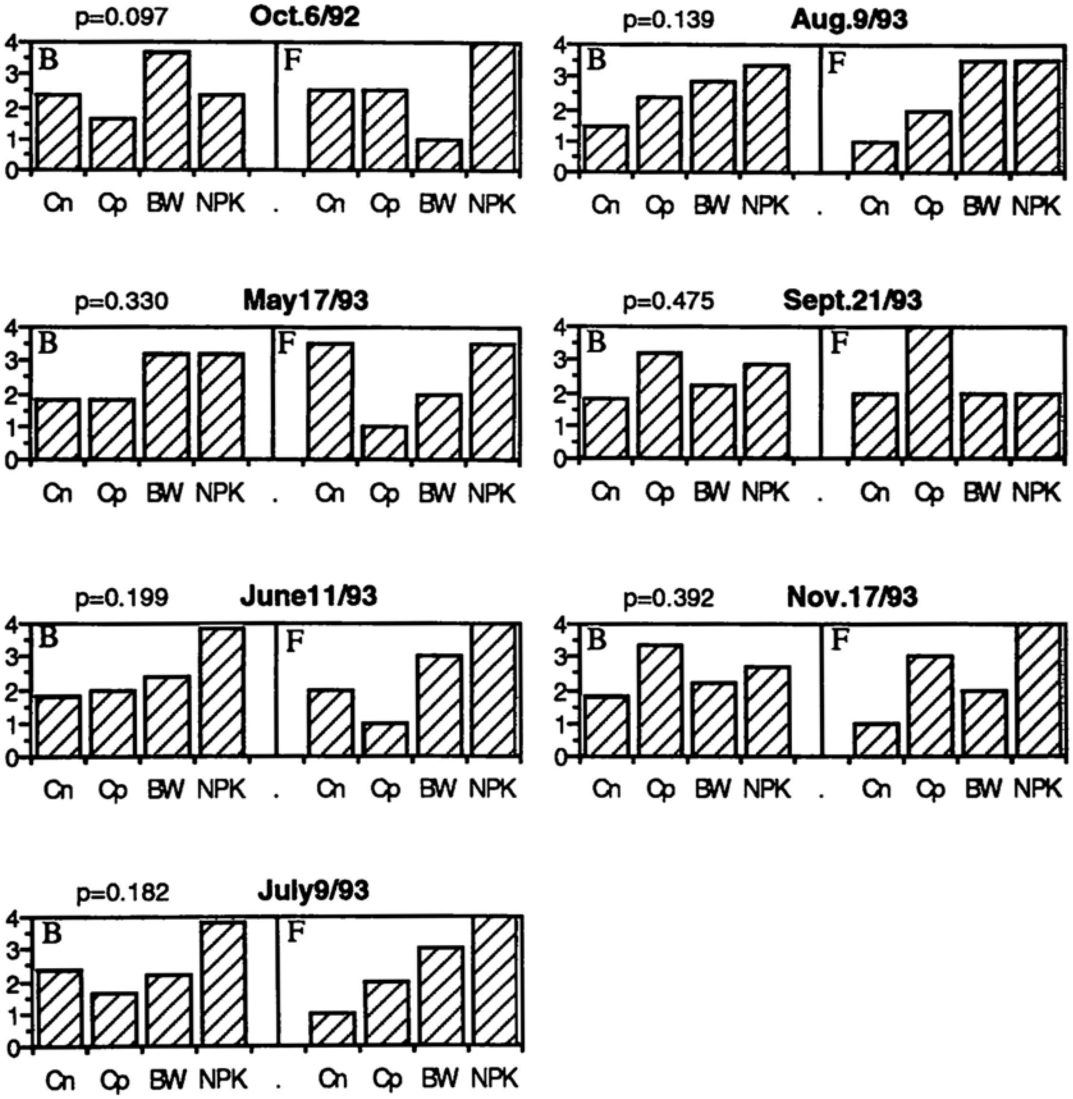
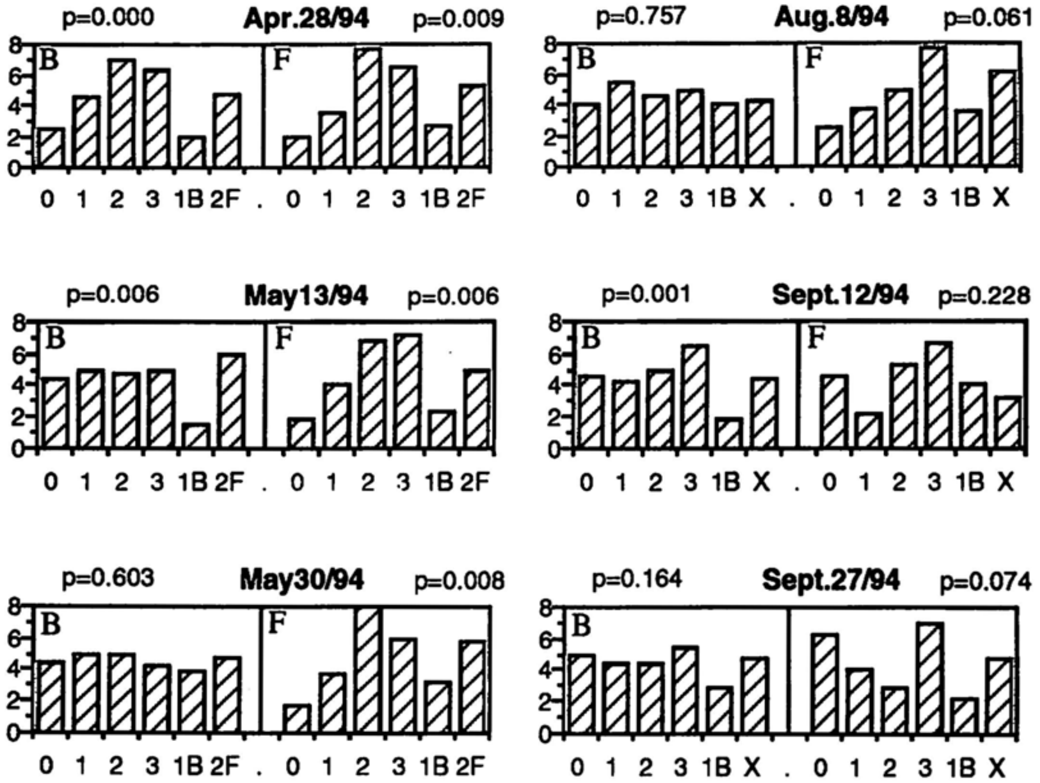
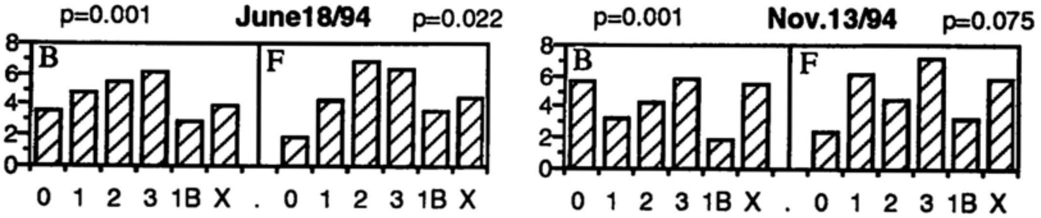


Figure B4. Visual greenness rankings for all main plots for 1992 and 1993. Values are averages for all Blocks and subplots.

→ *Fertilizer applied on Nov.17,1993.*



→ *Fertilizer applied on June3,1994*



→ *Fertilizer applied to plot OF3 on July1,1994.*

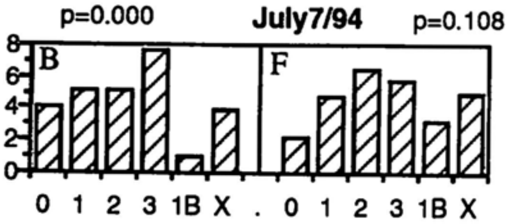


Figure B5. Visual greenness ranking for all subplots for 1994. Values are averages for all Blocks and main plots (except NPK). Values for individual main plots are provided in Section VII-Appendix 3.

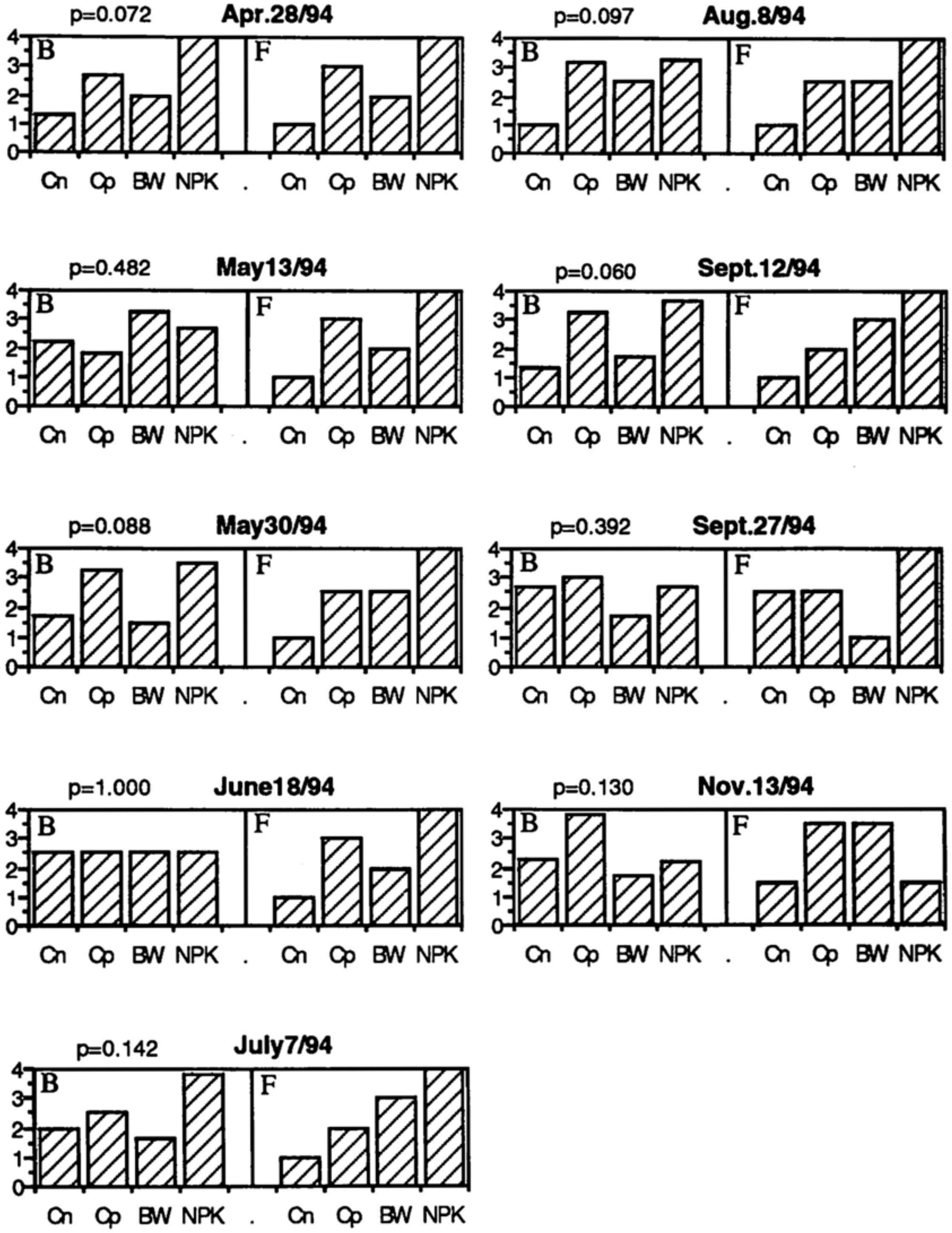


Figure B6. Visual greenness rankings for all main plots for 1994. Values are averages for all Blocks and subplots.

Table B1. Chlorophyll SPAD values for OF subplots for Cn main plots on one Block on the B field, and one Block on the F field. Values are means for five blades.

Sept. 22, 1992			July 13, 1993			Sept. 27, 1994		
Subpt	B (B3)	F	Subpt	B (B1)	F	Subpt	B (B2)	F
OF0a	32.9	32.6	OFOa	39.4	27.0	OFOa	36.7	33.9
OF0b	35.7	34.9	OF0b	38.3	31.5	OF0b	39.9	33.7
OF1a	36.5	34.2	OF1a	36.8	31.6	OF1a	39.8	34.7
OF1b	37.1	31.4	OF1b	38.0	35.8	OF1b (1B)	41.5	31.3
OF2a	36.5	36.2	OF2a	38.9	38.5	OF2a	40.9	34.4
OF2b (2D)	37.2	31.3	OF2b (2D)	36.1	34.8	OF2b	41.9	38.6
OF3a	36.1	36.5	OF3a	41.1	44.4	OF3a	40.4	35.2
OF3b	42.1	35.9	OF3b (3L)	37.1	34.8	OF3b (3X)	43.1	36.4

Table B2. Chorophyll SPAD values measured on December 6, 1994. Values are averages for 10 leaves.

	Chlorophyll in SPAD Units	
Subplot	B field (B1)	F field (B4)
Cp0	43.3	45.6
Cp2	41.8	43.6

C. Species composition

The turf on the fertility plots was established by seeding "Ecomix", a custom mixture of grasses (20% Haga Kentucky bluegrass, 20% Palmer perennial ryegrass and 60% fine fescues composed of 35% Reliant hard fescue, 15% Koket and Wilma chewing fescue, and 10% Fortress creeping red fescue). To determine whether the fertility regime influenced relative success of the different grass components, grass composition was examined in June of 1993 after the first winter, and again in the spring of 1995, three years after seeding.

We had expected that the clover seeded in the plus-clover mixture plots in 1992 would flower in 1993 (Turkington and Burdon, 1983), and that we would begin to see spread of clover from that source into the fertility plots in 1994. There turned out to be a very large seedbank of clover on the B Field which produced an abundance of clover in 1993. This complicated the experiments, but it also allowed us to examine the effects of fertility regime on appearance of clover.

On the F field, clover developed by radial spread from a few initial plants, producing the distinct patches of clover which are considered very unattractive. Collectively, the information we gained on clover allowed us to formulate different strategies for either encouraging or discouraging clover in ecologically managed turfs (Section IV).

Manual weeding kept weeds at horticulturally desirable levels, so we did not anticipate large differences in weediness, or to be able to discern effects of fertility on the potential for weed invasion. We documented the hours required for weeding in each year. Manual weeding was interrupted for a period following completion of the formal experiments in December of 1994. Documentation of weed cover at the end of August 1995, provided information on weed pressure in the absence of weeding, and how that is influenced by fertility regime.

Methods

In 1992, a list of weed species was compiled. Notes were made on their distribution and abundance.

Visual estimates of percent cover and species composition of the seeded grasses (divided into categories of Kentucky bluegrass, perennial ryegrass, fine fescues), weed cover and composition and clover cover were made on all subplots and on NPK main plots on June 11, 1993, and in fall94/spring95 on OF0 and OF2 subplots and NPK main plots. In the latter case, cover by grass, clover and weeds was estimated on September 8, 1994 and the proportion of Kentucky bluegrass, perennial ryegrass and fine fescues in the grass component were estimated over a two week period in late May/early June, 1995. Visual estimates of percent cover by clover and weeds were again made for OF0 and OF2 subplots and NPK main plots on August 30, 1995.

BOX 5: Species and cultivars of grasses.

Kentucky bluegrass - *Poa pratensis*

Description of species

Kentucky bluegrass is considered "the" fundamental cool season perennial turfgrass and is currently the most important species in use in most temperate zones. It is most often the largest component in most domestic, commercial, and professional seed mixtures. Full sun, good drainage, pH 6-7, and moderate fertility favors Kentucky bluegrass. Kentucky bluegrass is very winter hardy and has good wear tolerance. Under medium management, it produces a very high quality, dark green turf and with adequate moisture it will remain green and active in summer conditions. However, under an extended summer season of heat and drought stress, it will go dormant. Spring seed establishment should be avoided as the seedlings tend to be slow to germinate and have low vigor and competitive ability. Thatch can build up under high fertility and/or when growing on soils which have poor drainage. Recommended mowing height is 4 - 5 cm or 1.5 - 2 inches and recommended N application is 150 - 200 kg N per ha or 3 - 4 lbs N per 1000 sq ft per year.

Description of cultivars

Gnome: This Kentucky bluegrass variety produces a turf of excellent quality and vigor. Gnome is extremely drought tolerant and is a very competitive selection among Kentucky bluegrass varieties. Gnome also offers very good resistance to many turfgrass diseases.

Haga: Haga is a "newer" low growing selection known for its very quick establishment of good quality, medium textured turf with good density, color and excellent wear tolerance. Haga offers an early spring green-up and good maintenance of its color for the entire season. Haga possesses excellent damage recovery potential.

Perennial ryegrass - *Lolium perenne*

Description of species

This species is often described as a "short lived" perennial grass but many of the newer cultivars are quite long lived. Perennial rye has been utilized mostly in the industry as a 20% component of broader mixtures and serves well as a nurse grass in many Kentucky bluegrass turf mixtures because it germinates rapidly and well, even at low temperatures (5-8 °C). It provides a medium/fine textured turf with good density, good color, mowability and wear tolerance. Perennial rye is a low thatch accumulator and has good shade, drought, and disease tolerance. New cultivars are also very winter hardy. Recommended mowing height is 2 - 5 cm or 0.75 - 2 inches with a varied mowing schedule in terms of seasonal frequency as well as height of cut. Recommended N application is 150 - 200 kg N per ha or 3 - 4 lbs N per 1000 sq ft per year.

Description of cultivars

Palmer: This variety is described as a "leader" among adapted turf type perennial ryegrass. Palmer has very quick establishment and will produce a fine leaved turf of excellent color, density and quality. Palmer is very heat and drought tolerant, has good wear tolerance and good resistance to leaf spot, crown rust and brown patch diseases.

Fine fescues - *Festuca* spp.

Description of species

Fescues, and in particular fine leaved fescues, are widely used throughout the turfgrass industry particularly in mixtures with Kentucky bluegrass because of the complementary compatibility of this species with many others. They germinate quickly have a fibrous dense root system and high tiller density and will produce a very fine textured turfgrass stand of good color and reasonable quality. Fescues adapt well in both shade and sun and are very drought resistant. Low management varieties thrive in well-drained soils of lower fertility. Thatch will tend to accumulate on turf with high fescue content as the leaf sheaths have a high lignin content. Fescues tend not to be very disease resistant, have moderate heat and wear tolerance; but slow recuperative potential. The recommended mowing height can be conditionally anywhere between 5 - 13 cm or 2 - 5 inches and the N recommendation is 75 - 125 kg N per ha or 1.5 - 2.5 lbs N per 1000 sq ft per year.

Description of cultivars

Koket chewings fescue : Described as a non-creeping bunch type fescue that will produce a strong dense turf. It is adapted for sun or shade and can survive well on poor soils, with low fertility and drought conditions. Koket offers excellent disease resistance, fast germination and is a very compatible variety for use in seed mixtures.

Wilma chewings fescue: As well as possessing most of the attributes of fine fescues in general, Wilma is noted for its quick spring green-up and excellent color. It can provide a good quality, high density turf and offers excellent shade tolerance and disease resistance to leaf spot and dollar spot.

Fortress creeping red fescue: Fortress is a spreading red fescue with a strong fibrous root system with creeping rhizomes. It is an excellent low maintenance cultivar with good color and is tolerant of dry, low fertility and acidic soils. Fortress also has good tolerance to salt and performs well in mixtures and blends.

Reliant hard fescue: This low growing fescue is best known for its extremely low maintenance requirements and high endophyte content. Reliant produces a leafy, fine-textured turf of good dark color. It has very low water and fertility requirements, it is adapted to sun or moderate shade, is competitive and performs well on poor soils with little or no maintenance. Reliant also offers improved disease resistance and cold tolerance.

Tall fescues - *Festuca arundinacea*

Description of species

Although a few tall fescues had been in cultured use for decades, they were typically used as utility grade varieties and applied to marginal or low maintenance areas as well as athletic fields. With adaptation and improvement newer "Turf Type" tall fescues have increased potential usage into professional, commercial and residential lawn applications. "Turf Type" tall fescues are long lived perennial grasses of bunch type growth, with dense fibrous roots and a very dark green color. Typically, tall fescues are described as coarse textured yet many newer varieties possess finer blade and texture qualities. Tall fescues are known to possess excellent drought resistance, heat and wear tolerance as well as having good insect and disease resistance. They adapt well from sun to moderate shade and are low thatch accumulators and manage very well on reduced water and fertility inputs. Tall fescues can be slow to establish, are known to be susceptible to snow molds and winter hardiness can decline significantly in more northern applications. Seed mixtures using tall fescues typically recommend a 60% - 70% tall fescue component for stand compatibility and quality. Overseeding practices are recommended for maintenance of solid stand density. Recommended mowing height can vary from 4 - 7.5 cm or 1.5 - 3 inches or even 10 cm (4 inches) cut every 14 days for low maintenance areas. Recommended N application is 100 kg N per ha per year or 2 lbs N per 1000 sq ft per year.

Description of cultivars

Tribute : Introduced in 1988, Tribute offers improved appearance qualities, stress tolerance and disease resistance. It is described as moderately low growing with medium leaf texture and excellent dark green colour. It is adapted for full sun to moderate shade, shows good wear tolerance and is a medium-low thatch producer. Tribute is promoted as having medium-low maintenance requirements.

Rebel Jr. : Known for its extremely dark green color and lower, slower growth habit, Rebel Jr. is promoted as a "low maintenance" tall fescue variety. It is adaptable to sun or shade, it possesses a deep and dense root system and shows excellent drought tolerance. Rebel Jr. is said to provide a good quality stand of turf with improved mowability and requiring lower than average N.

Sources used in the species and cultivar descriptions included:

(1) Halifax Seed Co., Turf Seed
Specification Manual (1992).

(2) Daniel and Freeborg, (1987).

(3) Roberts and Roberts, no date.

(4) Hurley, et.al. (1990).

(5) Advertisement for Reliant and Rebel Jr.
(Lofts Seed Inc).

For these observations, a 50 x 50 cm quadrat with 16 wire-mesh squares was placed in the center of each subplot. Percentage composition and cover were estimated visually by two observers, using the squares to help in estimating percent cover. The separate estimates of the two observers were averaged.

Additional observations on clover were made on August 20, 1992 in conjunction with biomass measurements and on August 6, 1993 and July 11, 1994 in conjunction with observations on diseases. In 1992, three 10 x 10 cm quadrats were placed at random in each subplot, and presence or absence of clover recorded. For the 1993 and 1994 observations, 50 x 50 cm quadrats with 16 wire mesh squares were placed in the center of each subplot and the number of squares in which clover was present was recorded. Three such quadrats were placed at random in each NPK main plot. These "quadrat frequency" data were converted to proportions by dividing by 16. For statistical analysis, data were arcsin-squareroot transformed.

In mid-July, 1994, the size and location of discrete clover patches on the F field was documented by Jennifer Hayes (Biology student at Nova Scotia Agricultural College) as part of a class project; she contributed the raw data to the project. The lengths of major and minor axes of the patches, which tended to be elliptical in shape, were recorded, and the area of each patch estimated using the formula for an ellipse.

On July 23, 1993, we conducted semi-formal observations on the size, color and nodulation of clover. We examined all main plots, and subplots on Blocks 3 and 4 for clover size and color, recording semiquantitative data of the nature "clover uniformly small & dark green", or "approximately 20% light green plants, 80% dark green plants" etc. Chlorophyll and leaf size were measured on selected plants to provide additional descriptive information and reported values are means for five plants. At five locations, adjacent large/light green and small/dark green plants were carefully removed from the soil and examined for the pattern of nodulation. Plants from a BW main plot where plants were uniformly dark green were also examined.

Fertility effects on clover abundance

The most prominent change in the species composition over time was the appearance of abundant clover on the B field beginning in August, 1992. The clover was apparently established from a large seed bank under the old turf. The clover was distributed in small, irregularly shaped patches which did not appear sharply demarcated from the clover-free areas (Photo 7b). There was no flowering in 1992, however, flowers appeared in 1993 and 1994 with most flowering occurring roughly from the last week in June through the month of July to the first or second week in August. On the F field, clover invaded by radial expansion of clonal patches (Photo 7a).

Figures C1 and C2 show the relative clover abundance in relation to main plot treatments and to increasing levels of organofertilizer over the three field seasons, as indicated by the quadrat frequency data. Main points of interest are as follows:

B field

- In the first year, clover was much more abundant on the Cp main plots than on Cn and BW main plots. The high abundance of clover in Cp plots resulted in a visually distinct and sharp transition between Cp and other main plots.

- In all three years clover was least abundant in the BW main plots compared to other main plots

- Brewery waste at all levels of organofertilizer was much more suppressive of clover than was NPK (applied at 3 lbs N per 1000 sq ft per annum).

- In 1992 and 1993, the NPK values were slightly lower than the Cp3 values but well above that of BW3. In 1994, NPK had a higher percentage of clover than any of the OF3 subplots in Cn, Cp and BW main plots.

- There were overall trends for a positive effect of increasing organofertilizer on clover abundance in 1992 and 1993, however in 1994 the trend was for a negative effect of increasing organofertilizer on clover abundance.

F field

Figure C2 shows the relative clover abundance in relation to main plot treatments and to increasing levels of organofertilizer on the F field in 1994. Data on size and number of clover patches in mid-July of 1994, are given in Table C1, and Fig. C3 shows the size distribution of the patches. Main points of interest are as follows:

- A few individual clover plants were noted in August of 1992. Distinct clonal patches with sharply demarcated borders appeared in 1993 (Photo 7a). These expanded and became more numerous in 1994 and by mid-July, there were 86 individual patches covering 21% of the experimental area (Table C1).

The largest of these patches (6 m^2) probably developed from coalescing of two or more individual patches. Patches of less than 0.5 m^2 in area accounted for 43% of the total number of patches (Fig. C3). Assuming these were initiated in 1994, then "recruitment" of patches is estimated as 0.08 patches per m^2 (or 1 patch per 12.5 m^2) per year. The larger of the patches (3-4 m^2), were probably two years old. This suggests that clover can grow out by extension of stolons at a rate of 1.5-2.0 m per year. Stolon elongation rates of up to 3.8 cm per week are reported in the literature (Turkington and Burden, 1983).

- In 1994, clover exhibited positive responses to organofertilizer on the Cp main plot, and negative responses on the Cn and BW main plots (Fig. C2), however the statistics suggest that little credence if any should be given to these apparent trends.

- Percent area covered by clover patches in 1994 (Table C1) was lowest on the three mixture plots which received fertility treatment equivalent to Cp3 (compost incorporated and 3 lbs organofertilizer-N each year).

We also made visual estimates of clover cover on June 11, 1993, September 9, 1994 and August 30, 1995 (Table C2).

- The 1993 and 1994 data show trends similar to those described above on the basis of quadrat frequency data. Estimates of clover cover for June 10, 1993 are lower than for Sept. 9, 1994, which is contrary to the trend evident from quadrat frequency data comparing August 6, 1993 with July 11, 1994. However, the difference could be due to differences in the time of observations. In another study (Vessey and Patriquin, 1984), we observed clover cover to increase through June reaching its maximum at the end of June/early July and then remaining at that level until late fall.

- The August 1995 observations (Table C2) followed a period of no fall (1994) or spring (1995) fertilization on the B field; 1 lb N as organofertilizer was applied to the whole of the F field in June, 1995. The data show a large increase in the cover by clover on NPK plots on the B field (19.2% in 1994, 57.6% in 1995) but not on the F field (5% 1994, 3% 1994). Overall, clover decreased on the F field (compare Block figures, Table C2) and remained about the same on the B field.

Color, size and nodulation of clover

- In 1993, we noted large variation in greenness and size of clover plants between plots, and in some cases within plots. A survey on July 23 showed that overall, there was a trend for darker green plants to have smaller leaves (Fig. C4). Both types had active, red nodules, but invariably, the light plants had more nodules, particularly near the tops of roots. The smaller greener plants had fewer, but larger nodules, and usually none near the top of the roots (Photos 8a,b).

These differences in nodulation and their correlation with color can be attributed to differences in levels of mineral N in the soil at the time the roots were first formed. In dark green plants, it was apparently high enough to meet plant demand for N (giving dark green leaves) and at the same time inhibit nodule formation in the dark green plants. The light green plants in contrast were N deficient resulting in slightly chlorotic leaves, and in more nodulation. It is very typical for plants to be slightly chlorotic when they are very actively forming nodules, as much of the mineral N is diverted to nodule formation. After the plants became well nodulated and provide ample inputs of N through N_2 fixation, the leaves became darker (Sprent and Thomas, 1984). Mineral N suppresses nodule formation when it goes above about 2mM (Streeter, 1988) which is the equivalent of 5.6 ppm nitrate-N assuming 20% moisture. The critical events in formation of nodules occur near the growing apex, and potential infection zones remain susceptible to infection for only 12-24 hours (Bhuvaneswari et al.,1981). Thus if mineral-N is high enough to inhibit nodulation when roots start growing, there will be no nodules on the older parts of the roots. (There appears not to be information in the literature pertaining to leaf size and N deficiency.)

- We noted that there was a predominance (circa 90%) of the larger, lighter green plants on the mixes+clover plots that were established on compost and did not receive top dressings of organofertilizer, while on the mixes-clover plots which received top dressings, there were more nearly equal proportions of both types. Consistently, only dark, small plants were found on BW main plots on both fields, while there were both types on Cn, Cp and NPK main plots, with the lowest proportion of light types on the Cn plots. There was a tendency, but not absolute, for a lower proportion of light green plants with increasing organofertilizer, however, the main plot treatment appeared to be of greater significance.

These differences can be attributed to differences in the pattern of mineral N supply in the soil. Experiments with white clover have shown that plants supplied with continuous low nitrate absorbed more nitrate and had lower nodule mass than plants supplied with high nitrate for short periods (Davidson and Robson, 1986). Brewery waste likely provided a continuous release of N for the first summer and probably into 1993 which accounts for the uniformly dark green plants while on NPK plots there were pulse inputs of mineral N, and probably some heterogeneity within the soil. On Cp main plots, there was some N immobilization and likely there were patches of immobilization and net mineralization. Finally on Cn plots, there would be more uniformly low N, but still some heterogeneity. The pronounced differences in nodule size of clover plants was observed in mid-summer; it was progressively less pronounced later in the season, which is attributable to the N stressed, lighter green plants eventually receiving adequate N from N_2 fixation.

Interpretation of differences in abundance of clover

There were large differences in the development of clover under different fertility regimes. The level of soil mineral N (ammonium and nitrate-N) is well known to influence the proportion of legumes in legume-grass mixtures, that proportion decreasing as mineral N increases. The negative effect of N is due to grasses being able to respond to mineral N more quickly than legumes, while a deficiency of N favors legumes because of their N_2-fixing activity, providing the appropriate rhizobia are available in the soil to infect the plant (Ryle et al. 1981).

While legumes can often thrive in low N soil, they have requirements for other nutrients, and the availability of those nutrients, and the degree of shade, as well as level of N influence the success of the legume. White clover is considered to be a plant of intermediate soil fertility (Turkington and Burdon, 1983), although low pH strains are known (Snaydon and Bradshaw, 1962). White clover thrives under conditions of moderate acidity (pH 5.6-7.0) in which there is a high phosphorous and exchangeable calcium availability, while growth is curtailed on soils low in K. White clover grows on soils of differing textures. It is also shade intolerant (Turkington and Burdon, 1983).

The apparent positive responses of clover to organofertilizer on Cn and Cp plots in 1992 (Fig. C1) could have been due to the addition of P, K, Ca, or the liming effect of the organofertilizer. The suppression of clover on BW main plots is very likely due to the sustained release of mineral N from brewery waste in the first year. Analyses of nitrate in mid-summer of the first year show much higher levels on BW main plots on the B field than on other main plots (Section III.1I). The observation that consistently only smaller, dark clover plants were found on BW main plots, but mixtures of the two types were found on other plots, is further evidence that the BW main plots had a more sustained release of N, and supports our interpretation that this was the critical factor in keeping clover populations low.

It may seem surprising at first look that clover was more abundant on the NPK plots than on any of the BW plots. Clover on NPK plots was also more abundant than on the Cn0 plots, but it was less abundant than on the Cn3 plots. In the first year, NPK was incorporated in the soil, but there was no top dressing until September, thus the levels of free mineral N maintained in the soil were probably less or more variable than those maintained in BW plots, which is suggested also by the observations of light and dark clover plants. A stimulative effect of NPK (compared to Cn0) could have been due to the addition of P or K.

It seems likely that the events in the first year on the B field had a strong carryover effect in subsequent years, and that poor establishment of clover on BW plots in the first year was a factor restricting it on those plots subsequently. Only in 1995, did its' abundance start to overlap with that on Cn and Cp main plots. According to Turkington and Burdon (1983), "some sort of disturbance of the existing vegetation appears to be necessary for the establishment of new *T. repens* plants" and they note that seedlings are commonly observed growing on molehills, but are infrequent in undisturbed pasture. By the second year, the turf was well established at The Oaks and would tend to exclude new seedlings but not the spread of clover by stolons from existing plants. Thus poor establishment of clover in the first year would tend to carry over for at least one or two years. By 1994/95 on the BW main plots, sufficient plants had been established to provide many nuclei for clonal spread, and the N-mineralizing activity of the BW has largely dissipated, thus clover abundance began to approach levels found on other main plots.

Interestingly on NPK main plots on the B field, abundance increased progressively through 1992 to 1995 compared to Cn and Cp plots. There was a very large increase from 1994 to 1995, which suggests that NPK treated turfs have greatly increased susceptibility to clover invasion once fertilization is interrupted. The clover reached an average cover of >40% on the B field, and in large areas on some main plots it was close to 80 or 90% cover. This was visually unattractive, while the blend of clover and grass at more moderate levels of clover cover was considered attractive and acceptable (see Section VII-Appendix 2: Questionnaire Responses).

Clover on the F field developed from the spread of a few clonal patches, rather than from emergence of many seedlings as on the B field. The largest increase in area occurred between 1993 and 1994, after the turf was established. The generally thinner nature of this turf compared to the B field (Section III.1A), and creation of open patches as a result of red thread and pink snow mold infections (Section III.1F) could have contributed to its' apparently high susceptibility to clover invasion. Clover was least abundant on the mixture (minus clover) plots (Table C1). The higher value for Ecomix compared to Greenfast and tall fescues on these plots was probably due to high winter injury in Ecomix associated with the hard fescue component (Section III.1D).

Curiously, on the F field, clover abundance declined between 1994 and 1995, even on the NPK main plot, which is quite different from the B field. We cannot offer a good explanation for this. Calcium, P and K levels were equivalent or better than those on the B field (Section III.1I); only Mg was very much lower. The decline in clover could have been related in some way (negatively) to the apparently improved N nutrition of the field in the fall of 1994 as evidenced by the pronounced darkening up of the field (Section III.1B). Clover normally shows a decline over winter, and the decline is greater in N fertilized treatments (Harris et. al., 1983). Also the field received organofertilizer in June of 1995 while the B field did not, which could have restricted recuperation of the clover.

Fertility effects on grass species abundance

The proportion of perennial ryegrass, Kentucky bluegrass and fescues in the grass component of the vegetation was estimated visually on June 1993, and May/June 1995 (Table C3). Major points of observation are as follows:

- The average values for perennial ryegrass increased significantly on the B field with increasing levels of organofertilizer, while Kentucky bluegrass and fescues exhibit corresponding declines (Table C3).

Because the percentages must add up to 100, shifts in the percentages of a component do not necessarily correspond to shifts in the absolute amount of those components. For example, the apparent increase in ryegrass from 37.1 to 50.5% between OF0 and OF2 in 1995 is accompanied by decreases in both the Kentucky bluegrass component (46.0% down to 39.2%) and the fescue component (16.1% down to 9.3%). If the total biomass increased between OF0 and OF2, which is what would be expected, it is clear that ryegrass biomass increased and increased more than that of the other components, but the biomass of the others did not necessarily decrease as suggested by these figures - it may just not have increased as much as the ryegrass.

As a rough estimate of the actual biomass of the different species components, percent cover of the different components were multiplied by total (grass) biomass figures obtained in July of 1993 and August of 1994 (Fig. C5). In this figure, treatments are ordered according to the total biomass with total biomass increasing from left to right.

- These data suggest that in general, Kentucky bluegrass as well as ryegrass increased with increasing total biomass, while the fescues did not change much or in some cases declined at the higher biomass values. In 1993, ryegrass increased more at the highest biomass values (stippled areas in Fig. C5a,c,e) than did Kentucky bluegrass, while in 1994, the responses were more nearly parallel across the entire range (Fig. C5b,d,f).

- The values for the NPK main plots (plotted with the organofertilizer values) are somewhat anomalous, particularly in 1995, with lower values for ryegrass and higher values for Kentucky bluegrass compared to equivalent biomass values in the organofertilizer treatments.

These trends make sense in terms of the known characteristics of the groups; perennial ryegrass and Kentucky bluegrass generally respond to increasing fertility, while the fine fescues are not highly responsive (Watschke and Schmidt, 1992). The steeper increase of ryegrass at higher biomass levels in the earlier set of observations can be attributed to the earlier establishment of this species, however, by the second observation set (Sept. 1994), the Kentucky bluegrass had more or less caught up.

The high survival of perennial ryegrass was somewhat unexpected and is a significant feature. Amongst the cool season grasses, perennial ryegrass is the least tolerant of freezing stress (DiPaola and Beard, 1992). At The Oaks, perennial ryegrass was still a major component after three winters.

Fertility effects on weed abundance

Manual weeding at The Oaks was focused mostly on dandelion and plantain. Larger bare spaces left by hand weeding were overseeded and mulched in 1992 with ProMix Lite and in 1993 with ProMix Lite soil or compost (produced on site from tree leaves and grass clippings). In terms of the weed situation at The Oaks, significant observations are as follows:

- In the first year, grass was seeded in the late spring shortly after tilling the soil, and there were very high populations of annual weeds (Table C4). Weeding operations in the first year required approximately four person-days (Table C5).

- Few of the annual species were recorded in the second and third years (Table C4). Witchgrass was very prominent in the first year on the B field (Photo 9a), but there was very little of it in subsequent years. Thus it behaved like a nurse species, covering the surface rapidly, but giving way to other grasses subsequently.

- In the second year (1993), weeding required two person-days with proportionally more of that time on the B field than on the F field (Table C5).

- Prominent patches of bentgrass (*Agrostis* spp.) of 20-40 cm diameter appeared in the NPK Kentucky bluegrass subplots on the B field in 1993 (Photo 9e) and persisted through 1994 and 1995. A few patches occurred on the NPK main plot on the F field, but they did not appear on other NPK-Ecomix plots, or in any other main plots. Kentucky bluegrass is well known to be susceptible to this type of invasion by bentgrass (Watschke and Schmidt, 1992).

- In the third year, the F and B fields required two person-days of weeding, but proportionally more time on the F than on the B field, which was the reverse of 1993. (Table C5).

- The only persistently weedy area during the course of the formal experiment (1992-1994) was Block 3 in the vicinity of the Oak trees in the Cn main plot, which was shady and damp. Creeping buttercup was most persistent and not easily removed. Wild violets invaded and were removed. In the shady area of the mixture plots in Block 2, immediately adjacent to old turf which was >50% covered by plantain, plantain invaded a section of the mixture plots where we had been lax on weeding. However, it did not become a significant weed anywhere else on the B field.

No weeding was conducted in the spring and summer of 1995. The F field received organofertilizer at 1 lb N over the entire area in June, while the B field was not fertilized except for the SW corner where there was an outbreak of red thread. Weed cover was estimated on Aug. 30, 1995 for the same plots examined in 1994 (Table C2).

- Weed cover increased in all Blocks and treatments examined except for NPK main plots on the B field. It increased most and to horticulturally unacceptable levels on Blocks 3 and 4. The most prominent weeds in those blocks were violets, buttercup and plantain on Block 3, and dandelion, sorrel, violets and buttercup on Block 4. In Blocks 1 and 2, there were a few localized pure stand patches of sorrel, violets, and mouse-eared chickweed, and a few large dandelions and one plantain that would be considered unacceptable horticulturally. Otherwise weeds were not obtrusive on these Blocks.

- In all three years, weed cover was greater on Blocks 3 and 4 than on Blocks 1 and 2; the former had lower fertility as assessed by biomass and other indicators (discussed later in the report). Weed cover was lower on Cp and BW main plots than on Cn main plots, except for the F field in 1993. There was a weak trend of weed cover on organofertilized plots to be lower than that on OF0 plots on the B field, but not on the F field.

Interpretation

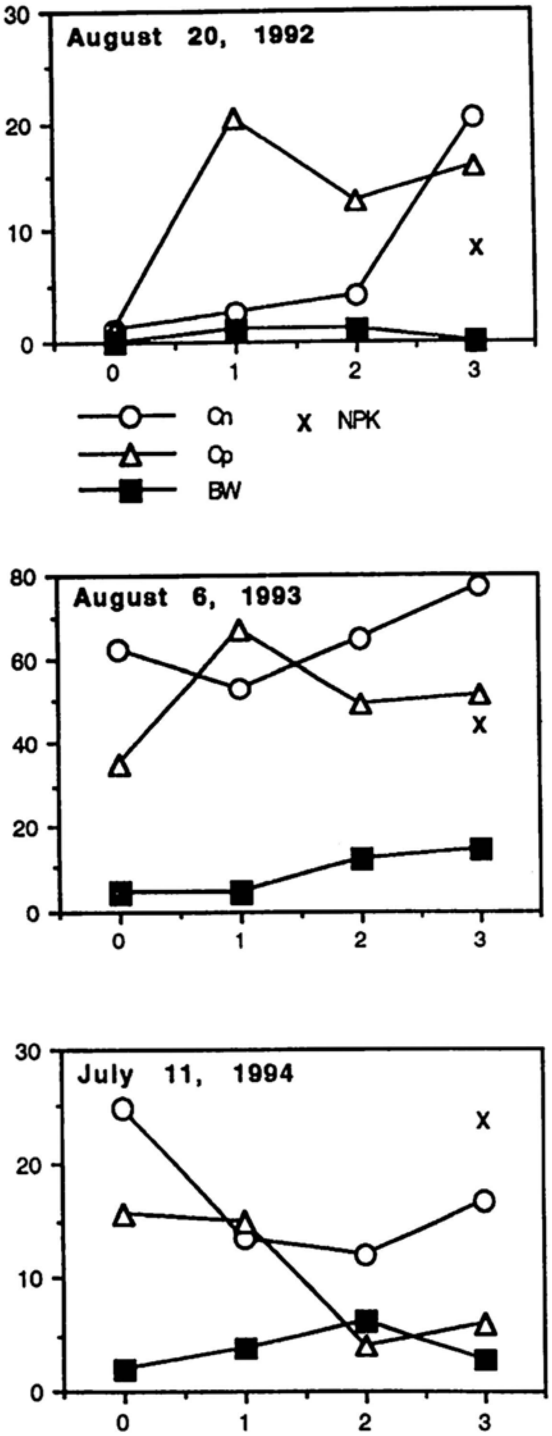
The large weed population the first year resulted from disturbance of soil with high weed seedbanks in the spring. Most of the weeds were annuals. It was important to remove the larger broad leaf types and overseed because of their shading effect and inhibition of germination of turf grasses. On the other hand, witch grass, which is an annual, served as an effective nurse species in the first year, and was only of minor abundance subsequently. We would except the weeding requirement to have been much less, had the turf been seeded in the fall. Fall planting is generally considered more desirable than spring planting because competition from annuals is reduced (Watschke and Schmidt, 1992). If there is a fallow with repeated cultivation before seeding, weeds can be reduced to almost nil in the seedbed, and those that do germinate are winter killed.

We attribute the differences between B and F fields in 1994 (more weeding required on F field) to the development of a very thick and healthy sward on the B field in 1993, while there was a lot of stress and loss to red thread on the F field (except where fertilized or where there was clover), which opened the sward up to invasion by weeds.

When weeding was stopped, weed cover increased in all treatments except in NPK main plots on the B field. The anomaly of the NPK plots can be attributed to the large increase in clover which is competitive with broad leaf plants (Turkington et al., 1979).

There was a strong negative effect of previous fertility treatments on weeds in 1995, a trend that was evident even at lower levels of weeds in 1993 and 1994. Generally in plant communities, diversity is low at very low site fertility, increases with fertility to a maximum at low to moderate fertility, and then decreases sharply with further increase in site fertility (Marrs, 1993). The weeds quickly developed to very high and unacceptable levels on the F field and Block 3 after regular fertilization and weeding were interrupted, but not on Blocks 1 and 2. These differences correspond to overall fertility gradients, with Blocks 1 and 2 having most consistently the highest verdure. Thus it appears in general terms that these turf communities (and others) operate close to the border between high fertility/low diversity and low fertility/high diversity and that towards the high fertility end, there is better natural control of weeds. Regardless, the sharp increases following one season of no-weeding illustrate the importance of timeliness in control of weeds in organically managed systems. It seems likely, that if the trend of no weeding were continued, high populations of weeds would develop on the B field.

Dandelion and plantain are the species considered the most unsightly in this region, and the ones that are most important to manually remove under organic management. In 1995, dandelion had already spread fairly widely although it still was not numerous on the B field. This species has small, easily dispersed seeds, however, they are non-persistent in the seedbank (Hill et al.,1989). Thus removing large populations that might have developed on a turf can reduce subsequent weeding demands. In contrast plantain has large seeds which are not readily dispersed over long distances, but the seedbank is long-lived (Hawthorn, 1974; Hill et al., 1989). Thus we observed plantain to be abundant only next to preexisting stands. It would obviously be very important to remove isolated new plantain plants from areas where it has not previously established (such as on Blocks 1 and 2 on the B field), to prevent the initial establishment of a new seedbank.



Split plot ANOVA - 1992

MP F (2,4): 2.25; p=0.221
Sp F (3,54): 2.74; p=0.052
MP*Sp F (6,54): 1.34; p=0.257
cv MP = 107%
cv Sp, MP*Sp = 29.5%

OF Linear Contrasts (p values)
All MP: 0.015
Cn: 0.080
Cp: 0.079
BW: 1.00

Split plot ANOVA - 1993

MP F (2,4): 2.25; p=0.133
Sp F (3,54): 2.74; p=0.428
MP*Sp F (6,54): 1.34; p=0.598
cv MP = 115%
cv Sp, MP*Sp = 13.5%

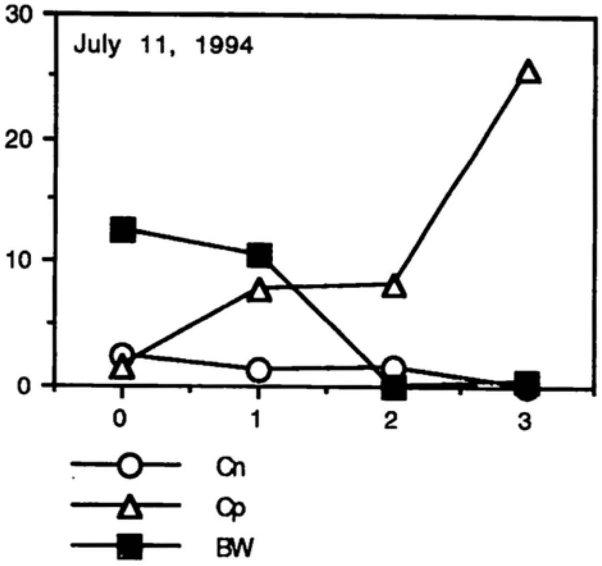
OF Linear Contrasts (p values)
All MP: 0.105
Cn: 0.358
Cp: 0.625 (q=0.286)
BW: 0.070

Split plot ANOVA - 1994

MP F (2,4): 2.25; p=0.052
Sp F (3,54): 2.74; p=0.252
MP*Sp F (6,54): 1.34; p=0.082
cv MP = 15.3%
cv Sp, MP*Sp = 6.8%

OF Linear Contrasts (p values)
All MP: 0.066
Cn: 0.182 (q=0.056)
Cp: 0.017
BW: 0.654 (q=0.289)

Figure C1. Relative abundance of clover at different levels of organofertilizer on the B field. Values are quadrat frequencies in percent, calculated from averages of arcsin-squareroot transformed data.



RCB ANOVA - 1994

Sp F (3,18): 0.18; p=0.908

OF Linear Contrasts (p values)
All Sp: 0.741
Cn: 0.428
Cp: 0.190
BW: 0.329

1992: No clover recorded in subplots except:
Cn-OF1: 9.2%
Cp-OF3: 9.2%

1993: No clover recorded in subplots except:
Cn-OF1: 8.6%
Cp-OF3: 14.7%
BW-OF3: 6.8%

Figure C2. Relative abundance of clover at different levels of organofertilizer on the F field. Values are quadrat frequencies in percent, calculated from averages of arcsin-squareroot transformed data.

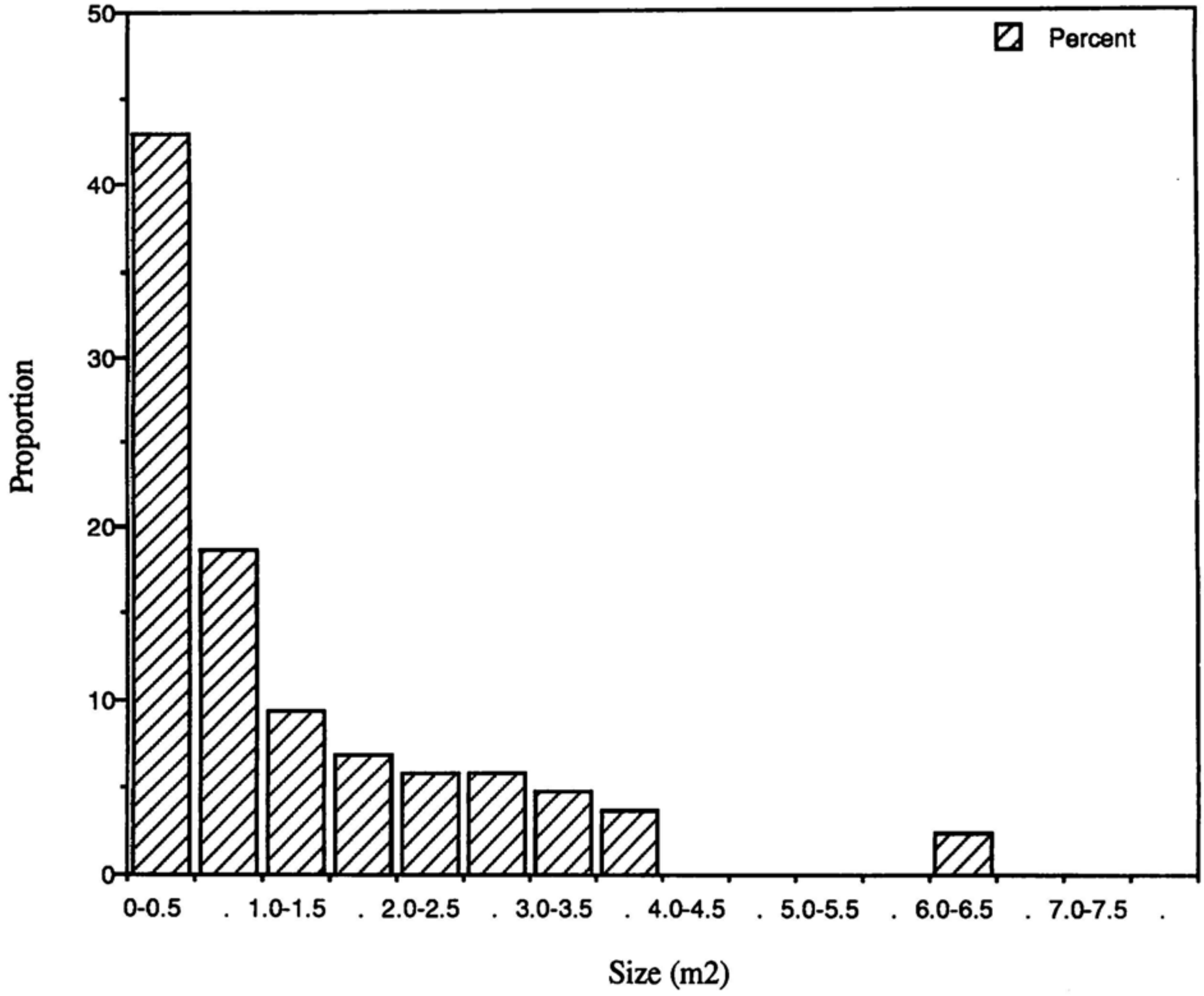


Figure C3. Clover patch size (m^2) distribution in July 1994 for the F field. Histogram is based on a total of 86 patches.

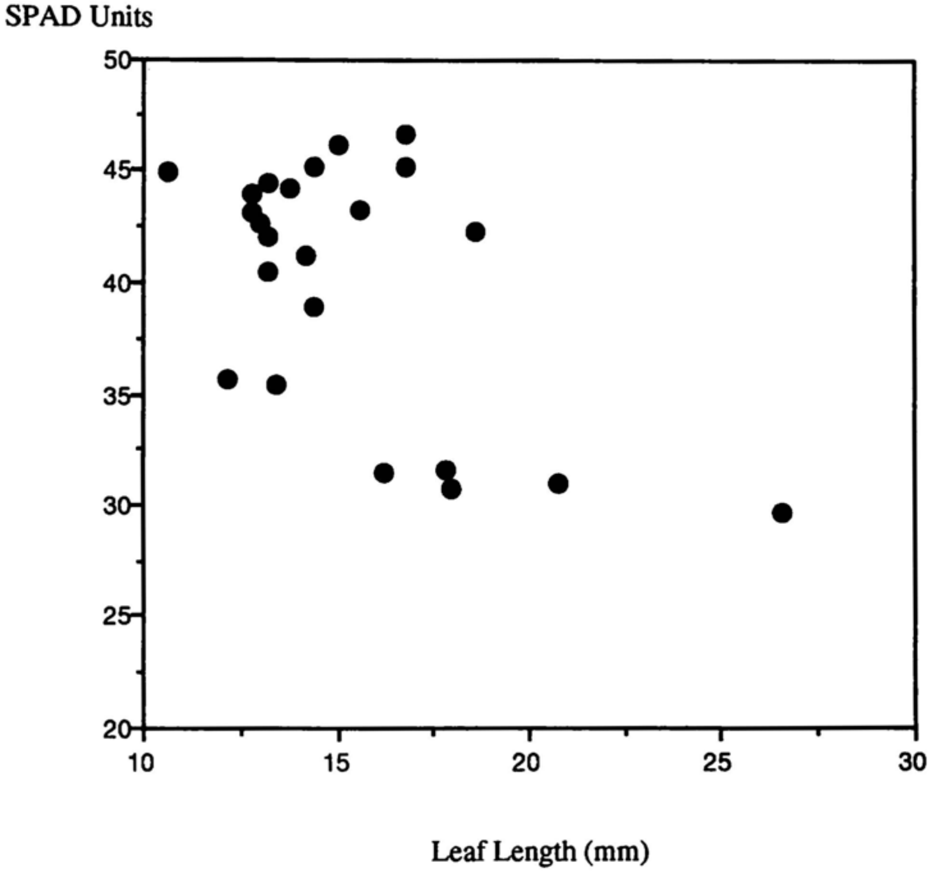


Figure C4. Plot of chlorophyll vs. leaf length of clover on July 23, 1993 (n=23).

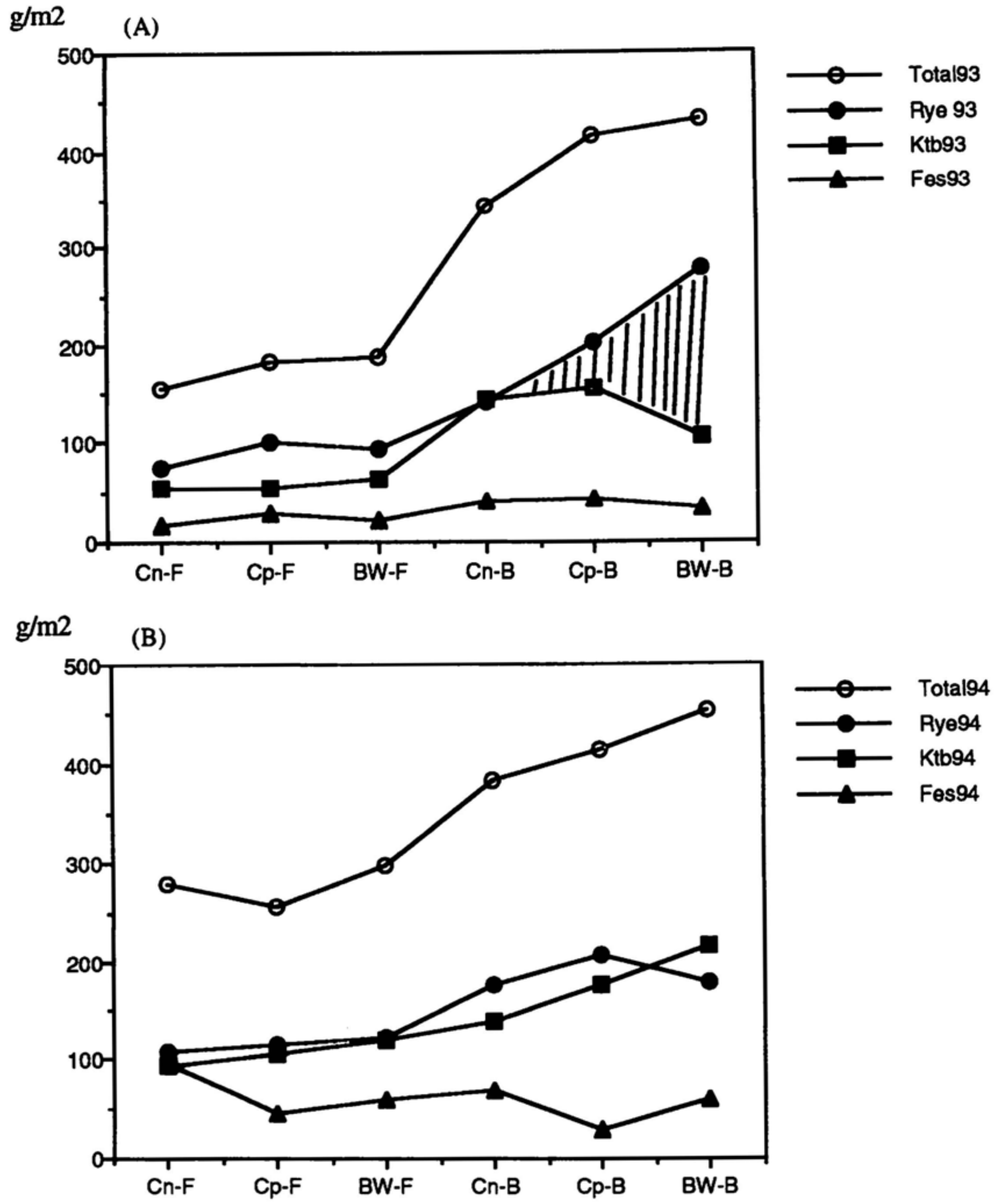


Figure C5 A,B. Total biomass of different species components and total biomass for main plots in July, 1993 and August, 1994. Biomass for differenct species was estimated by multiplying the %cover of the different components by total (grass) biomass. Treatments are ordered according to the total biomass with total biomass increasing from left to right. F and B refer to F and B fields.

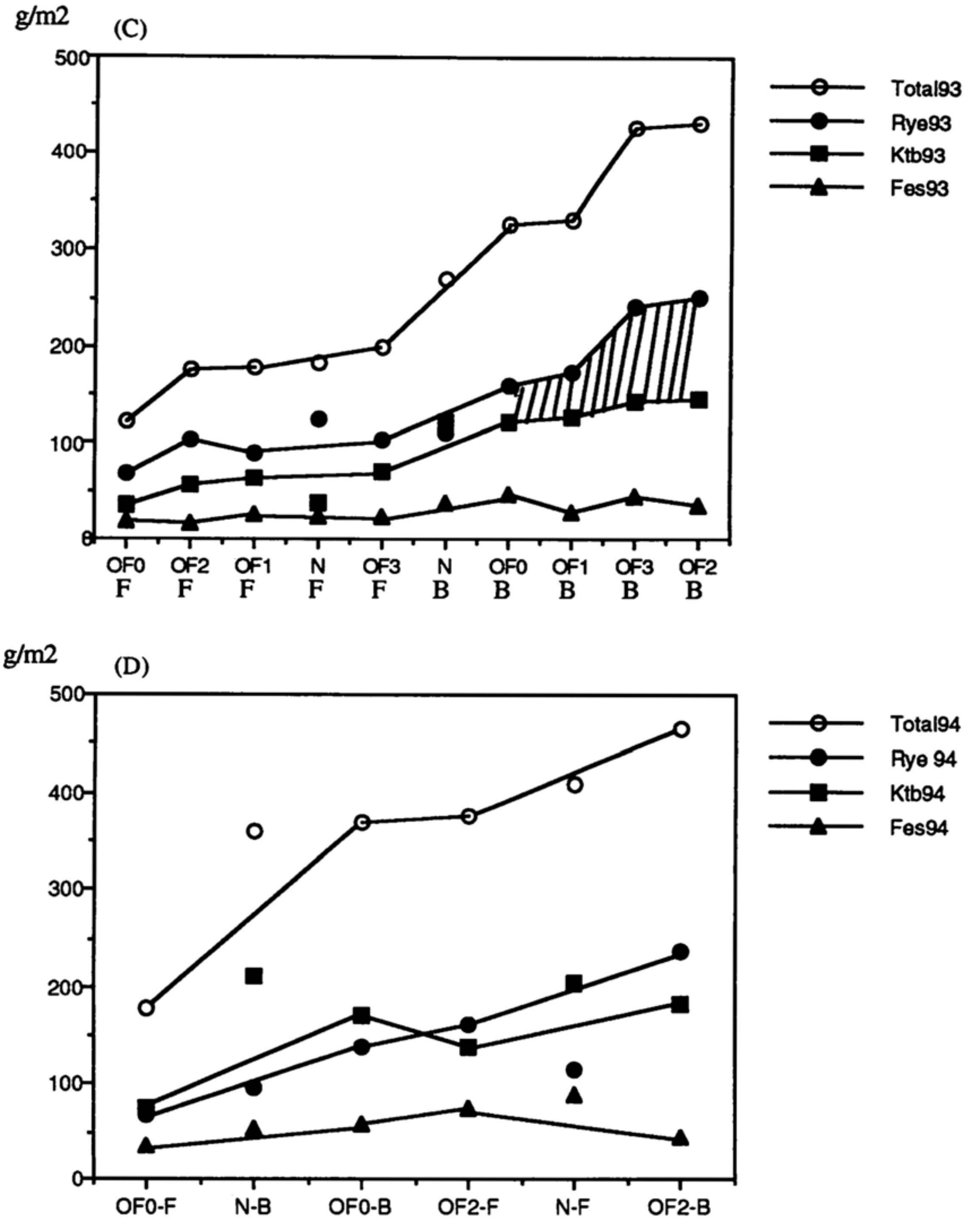


Figure C5 C,D. Total biomass of different species components and total biomass for organofertilizer subplots and NPK plots in July, 1993 and August, 1994. Treatments are ordered according to the total biomass with total biomass increasing from left to right. Values for NPK plots are shown but the lines to not join NPK values to other values. F and B refer to F and B fields.

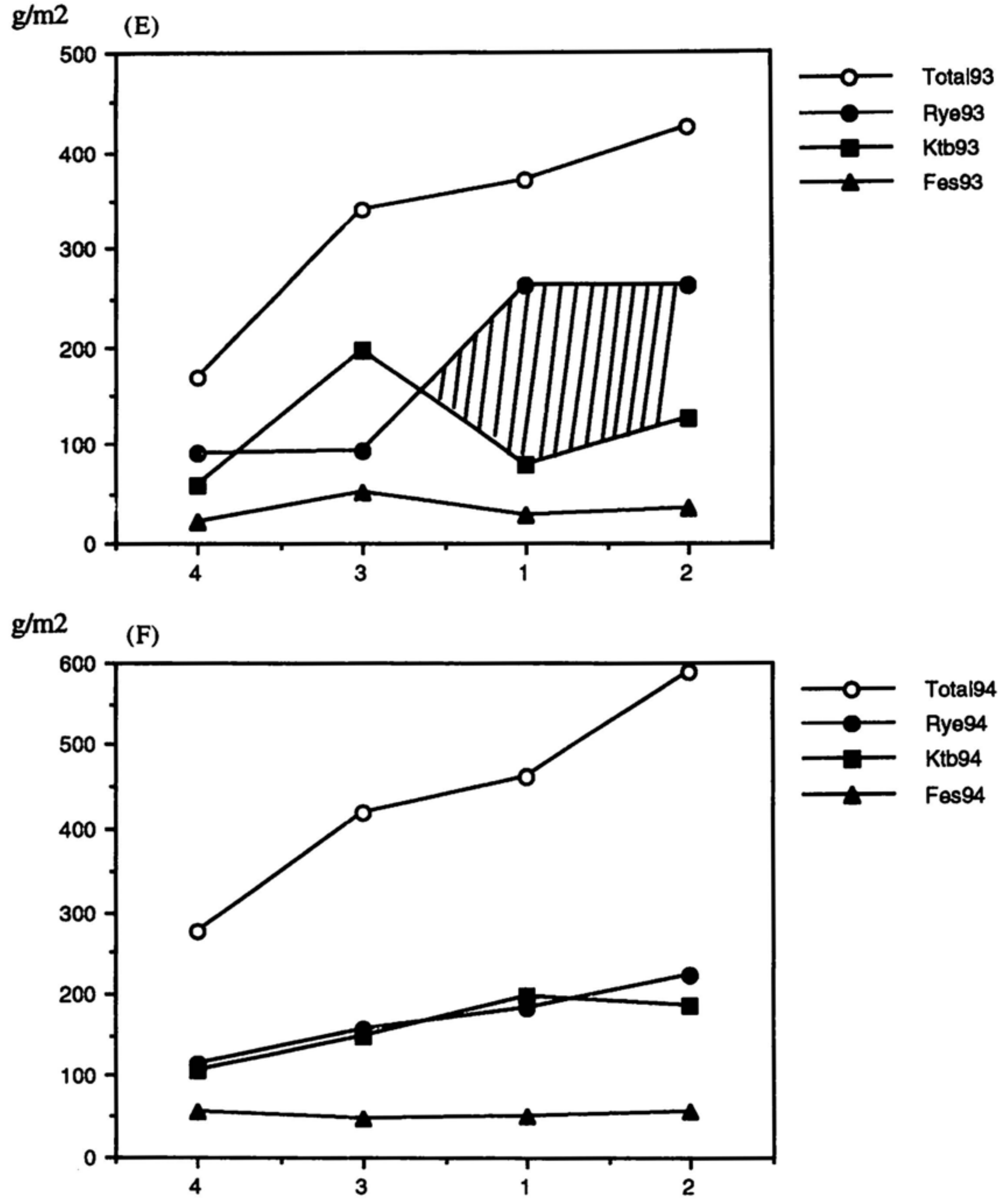


Figure C5 E,F. Total biomass of different species components and total biomass for Blocks 1-4 in July, 1993 and August, 1994. Treatments are ordered according to total biomass with total biomass increasing from left to right.

Table C1. Clover patch data from the F field in mid-July, 1994.

Section	Total Plot Area (m^2)	# Whole Patches in Plot	# Partial Patches in Plot	Clover Patch Size (m^2)	% Area Covered by Clover
Main Plots					
Cn MP	47.2	11	9	14.6	30.9
Cp MP	47.2	3	9	9.3	19.7
BW MP	47.2	7	8	11.8	24.9
NPK MP	40.0	5	7	8.3	20.6
Side/Cn-MP	52.1	10	2	7.5	14.4
Bott/Cn-MP	25.5	5	2	12.1	47.4
Bott/Cp-MP	27.7	7	3	11.4	41.0
Bott/BW-MP	31.8	6	2	9.7	30.4
Mixture Plots					
Tall Fescue	46.0	5	1	3.2	7.0
Ecomix	46.0	2	2	7.5	16.3
Greenfast	47.0	3	2	4.2	8.9
Total	468.3	64	47	99.5	21.2

Table C2. Grass-clover-weed composition of turf. Values are arithmetic averages of visually estimated %cover for each component. Statistical tests were performed on arcsinsqrt transformed data. Probability values are from Split plot ANOVA for Blocks 1-3, and RCB ANOVA for Block 4.

1993 Blocks 1 - 3

Trt	Grass	Clover	Weeds
OF0	94.3	4.4	1.3
OF1	93.9	5.2	0.9
OF2	91.0	8.6	0.4
OF3	93.3	5.8	0.9
NPK	95.8	3.3	0.8
OF: p	0.52	0.253	0.227

Trt	Grass	Clover	Weeds
Cn	87.9	10.6	1.5
Cp	93.1	6.4	0.5
BW	98.4	1.0	0.6
MP: p	0.030	0.036	0.668

1993 Block 4

Trt	Grass	Clover	Weeds
OF0	99,8	0	0.2
OF1	99.8	0	0.2
OF2	99.2	0	0.8
OF3	95.3	0	4.7
NPK	100.0	0	0
OF: p	0.321		0.321

Trt	Grass	Clover	Weeds
Cn	99.8	0	0.2
Cp	96.8	0	3.2
BW	99.1	0	0.9

1993 Block Averages

Trt	Grass	Clover	Weeds
Block 1	97.5	2.0	0.4
Block 2	94.5	5.4	0.2
Block 3	87.4	10.5	2
Block 4	98.5	0.0	1.5

Table C2. Continued...

1994 Blocks 1 - 3

Trt	Grass	Clover	Weeds
OF0	81.3	17.8	0.9
OF2	89.9	9.6	0.6
NPK	80.4	19.2	0.4
OF: p	0.053	0.061	0.275

Trt	Grass	Clover	Weeds
Cn	79.8	18.5	1.7
Cp	82.0	17.5	0.5
BW	95.0	5.0	0.0
MP: p	0.0005	0.0002	0.264

1994 Block 4

Trt	Grass	Clover	Weeds
OF0	74.3	23.3	2.3
OF2	91.7	3.3	5.0
NPK	93.7	5	1.3
OF: p	0.057	0.105	0.422

Trt	Grass	Clover	Weeds
Cn	75.5	17.5	7.0
Cp	78.0	20.0	2.0
BW	95.5	2.5	2.0

1994 Block Averages

Trt	Grass	Clover	Weeds
Block 1	93.0	6.8	0.2
Block 2	79.2	20.8	0.0
Block 3	84.7	13.3	2.0
Block 4	83.0	13.3	3.7

Table C2. Concluded.

1995 - August Blocks 1 - 3

Trt	Grass	Clover	Weeds
OF0	76.7	18.4	4.8
OF2	82.3	12.8	4.8
NPK-Eco	57.6	42.0	0.3
NPK-Ktb	54.5	39.9	6.1
OF: p	0.3892	0.3342	0.9984

Trt	Grass	Clover	Weeds
Cn	70.0	22.9	7.0
Cp	84.1	12.2	3.6
BW	84.3	11.7	3.9
MP: p	0.0939	0.1857	0.6547

1995 - August Block 4

Trt	Grass	Clover	Weeds
OF0	79.7	10.9	8.3
OF2	89.0	5.7	6.2
NPK-Eco	90.6	3.1	6.2
OF: p	0.1414	0.1835	0.0523

Trt	Grass	Clover	Weeds
Cn	82.0	8.6	10.9
Cp	88.2	7.8	3.9
BW	82.7	8.6	7.0

1995 - August Block Averages

Trt	Grass	Clover	Weeds
Block 1	78.9	17.2	3.9
Block 2	83.8	14.6	1.5
Block 3	75.7	15.1	9.1
Block 4	84.3	8.3	7.3

Table C3. Species composition of grass component of turf swards. Values are arithmetic averages of visually estimated %cover for each component. Statistical tests were performed on arcsinsqrt transformed data.

Blocks 1 - 3

	1993			1995		
Trt	Ktb	Rye	Fes	Ktb	Rye	Fes
OF0	38.3	45.3	16.4	46.0	37.1	16.1
OF1	40.8	50.3	8.9	.	.	.
OF2	35.6	56.4	8.1	39.2	50.5	9.3
OF3	35.8	53.3	10.8	.	.	.
NPK	45.0	40.8	14.2	59.2	24.2	17.5
OF: p	0.427	0.019	0.003	0.007	0.0001	0.005

	1993			1995		
Trt	Ktb	Rye	Fes	Ktb	Rye	Fes
Cn	46.0	40.0	14.0	37.9	44.6	16.0
Cp	40.8	47.9	11.2	43.2	49.3	7.9
BW	26.0	66.0	7.9	46.7	37.5	14.2
MP: p	0.260	0.173	0.274[a]	0.278	0.197	0.352

Block 4

	1993			1995		
Trt	Ktb	Rye	Fes	Ktb	Rye	Fes
OF0	30.8	53.3	14.2	43.3	36.7	20.0
OF1	35.8	50.0	14.2	.	.	.
OF2	32.5	58.3	9.2	36.7	43.3	20.8
OF3	35.0	52.5	12.5	.	.	.
NPK	20.0	67.5	12.5	50.0	28.3	21.7
OF: p	0.676	0.491	0.205	0.232	0.352	0.911

	1993			1995		
Trt	Ktb	Rye	Fes	Ktb	Rye	Fes
Cn	37.5	51.2	10.0	32.5	41.2	27.5
Cp	28.8	55.6	15.6	43.8	42.5	13.8
BW	34.4	53.8	11.9	43.8	36.2	20.0

Block Averages

	1993			1995		
Trt	Ktb	Rye	Fes	Ktb	Rye	Fes
Block 1	22.1	70.2	7.7	45.8	41.7	11.7
Block 2	31.7	59.6	8.8	40.0	47.7	11.7
Block 3	59.2	24.2	16.7	42.0	42.0	14.8
Block 4	33.5	53.5	12.5	40.0	40.0	20.4

Table C4. Weeds observed at The Oaks.

Annuals

1992	93-95	
	X	Annual Bluegrass (*Poa annua* L.)
	X	Barnyard Grass (*Echinochloa crusgalli* (L.) Beauv.)
X		Buckwheat, wild (*Polygonum convolvulus* L.)
X	XX	Chickweed, common (*Stellaria media* (L.) Cyrillo.)
	XX	Chickweed, grassy (*Stellaria graminea*)
X	XX	Cinquefoil, common (*Potentilla reptans* Linn.)
X	X	Crabgrass, small (*Digitari ischaemum* (Schred.) Muhl.)
X		Dock, curled (*Rumex crispus* L.)
X		Hempnettle (*Galeopsis tetrahit* L.)
XX		Lady's thumb (*Polygonum persecaria* L.)
XXX^{f}		Lambsquarter (*Cheopodium album* L.)
X		Medic, black (*Medicago lupulina* L.)
X		Shepherd's purse (*Capsella bursa-pastoris* (L.) Medic.)
X	X	Sorrel, yellow wood (*Oxalis stricta* L.)
X		Toadflax, yellow (*Linaria vulgaris* Mill.)
X		Wild radish (*Raphanus raphanistrum* L.)
XXX^{b}	X	Witchgrass (*Panicum capillare* L.)

Bienenial/Perennial

1992	93-95	
	XX	Bentgrass (*Agrostis* sp)
X		Blackberry (*Rupus hispidus* L.)
X	XX	Buttercup, creeping (*Ranunculus repens* L.)
X	X	Carrot, wild (*Daucus carota* L.)
XX	XX	Chickweed, mouse-eared (*Cerastium vulgatum* L.)
XX^{f}		Coltsfoot (*Tussilago farfara* L.)
X	XX	Dandelion. common (*Taraxacum officinal* Weber)
X	X	Dandelion, fall (*Leontodon autmnalis* L.)
X		Goldenrod (*Solidago* spp.)
X		Nightshade, bittersweet (*Solanum dulcamara* L.)
X		Pin Cherry (*Prunus pennsylvanica* L.)
X	XX	Plantain, broadleaf, (*Plantago major* L.)
X	X	Quackgrass (*Agropyron repens* L.)
X		Sorrel, sheep (*Rumex acetosella* L.)
X		Vetch, tufted (*Vicia cracca* L.)
XX	XX	Violets, field (*Viola arvensis* Murr.)
X	X	Yarrow (*Achillea millefolium* L.)

X	present;
XX	common in restricted locale
XXX	common over whole field (field indicated by superscript)

Table C5. Time required to manually weed the two fields at The Oaks from 1992 to 1994.

Year	**B Field**	**F Field**	**B Field**	**F Field**
	total hours	total hours	min/1000 sq ft	min/1000 sqft
1992	20	12	55	55
1993	20	3	55	14
1994	8	16	22	74

D. Winter hardiness

Meteorological conditions (Section VII-Appendix 1), plus the early developmental stage of the turf, resulted in conditions that were conducive to heavy winter injury in 1992/93. Winter injury was documented by estimating the percent of the area covered by apparently dead grass in spring. Differences in height gave an indication of which treatments began growth earliest in the spring. Photos 2 and 3 illustrate visually some of the observations described below.

Methods

Observations on winter injury and height of grass were made on May 17, 1993 and April 28, 1994. Percent winter injury was estimated visually for each subplot, (examining the whole 1.5 x 1.5 m subplot,) and three plots in the NPK-Ecomix and NPK-Ktb subplots. Heights were measured in five of 16 squares within 50 x 50 cm quadrats placed in the center of the subplots. Ranking observations are described separately.

Results

There was a lot of winter injury in 1992/93, made worse in a few areas by unauthorized foot and vehicle traffic in late October of 1992.

- Dormant fertilized OF2 plots exhibited least winter injury, greatest early growth in length (Fig. D1; Photo 2a), and best early season greening (Section III.1B).

Two sets of monoculture plots had been planted in 1992 for demonstration purposes, one under heavy shade in a part of the B field not used for experiments, and one in the open on the F field. These areas received compost, and organofertilizer at 3 lbs N per 1000 sq ft.

- The plots planted in the shade were almost completely winter-killed.

- In the open, there was high winter injury of the Reliant hard fescue. On the other hand, Palmer perennial ryegrass exhibited amongst the least winter injury (Table D1; Photo 3).

The high level of winter injury of the hard fescue probably accounts for the generally high figures for winter injury in the fertility experiments, as this species was a major component of Ecomix.

- There were overall trends of decreasing winter injury with increasing organofertilizer on both fields, but with the dormant fed OF2 level exhibiting the lowest winter injury (Fig. D1). Main plot and MP x Sp effects were not significant for the B field, although there was some suggestion from the figures that on the B field, Cp main plots exhibited better early season growth and lower overall winter injury than other treatments (Fig. D2).

In the fall of 1993, all fall fertilizer was applied as a dormant feed (on Nov, 17); only the OF2D treatment was dormant fed in 1992.

- Overall, there was much less winter injury in 1993/94. There were again overall trends for decreasing winter injury with increasing level of organofertilizer, and again, the Cp main plot seemed to exhibit the least winter injury on the B field (Figs. D3, D4).

- Height data show trends similar to those observed for ranking of greenness (Section III.1B), with no increase above the OF1 level on the B field, while on the F field, there was additional growth at the OF2 but not the OF3 level.

- Formal observations were not made in the spring of 1995 but overall, there was good winter survival, and The Oaks site greened up as quickly as the earlier-greening residential sites nearby (Photo 2b).

The Kentucky bluegrass plots stood out during the winter due to an overall dark coloration which was associated with distinct reddening and some necrosis towards the tips (Photo 13d). Discoloration of Kentucky bluegrass in the Ecomix plots was also observed, but appeared to be less prevalent than among the Kentucky bluegrass in the pure Kentucky bluegrass plots. As the plots had not been fertilized in the fall, we suspected that a nutrient deficiency might be involved, however, nutrient analyses did not reveal any major differences. Soil analyses did reveal the soil to be more acid than the Cn plots (Section III.1I, Table I6). Another possible explanation was that since the pure Kentucky bluegrass plots were a blend of two cultivars (Haga and Gnome), and only one was included in Ecomix (Haga), it is possible that the reddening was associated with the distinctive cultivar (Gnome) in the Kentucky bluegrass plots. The condition dissipated by the third week in May.

Table D1. Winter injury in monospecific demonstation plots examined on April 29, 1993.

Variety	**Mixes***	**Winter Injury (%)**	
		B field (shade)	*F field (open)*
Koket (chewing fescue)	E,G	50	40
Wilma (chewing fescue)	E	90	40
Fortress (creeping red fescue)	E,G	90	20
Reliant (hard fescue)	E	90	70
Haga (Kentucky bluegrass)	E,G,K	95	20
Gnome (Kentucky bluegrass)	K	100	65
Palmer (perennial ryegrass)	E,G	50	20
Rebel Jr. (tall fescue)	TF	90	65
Tribute (tall fescue)	TF	95	35
Clover		100	20

* Mixes in which the variety was used:
E= Ecomix
G= Greenfast
K= Kentucky bluegrass
TF= Tall Fescues

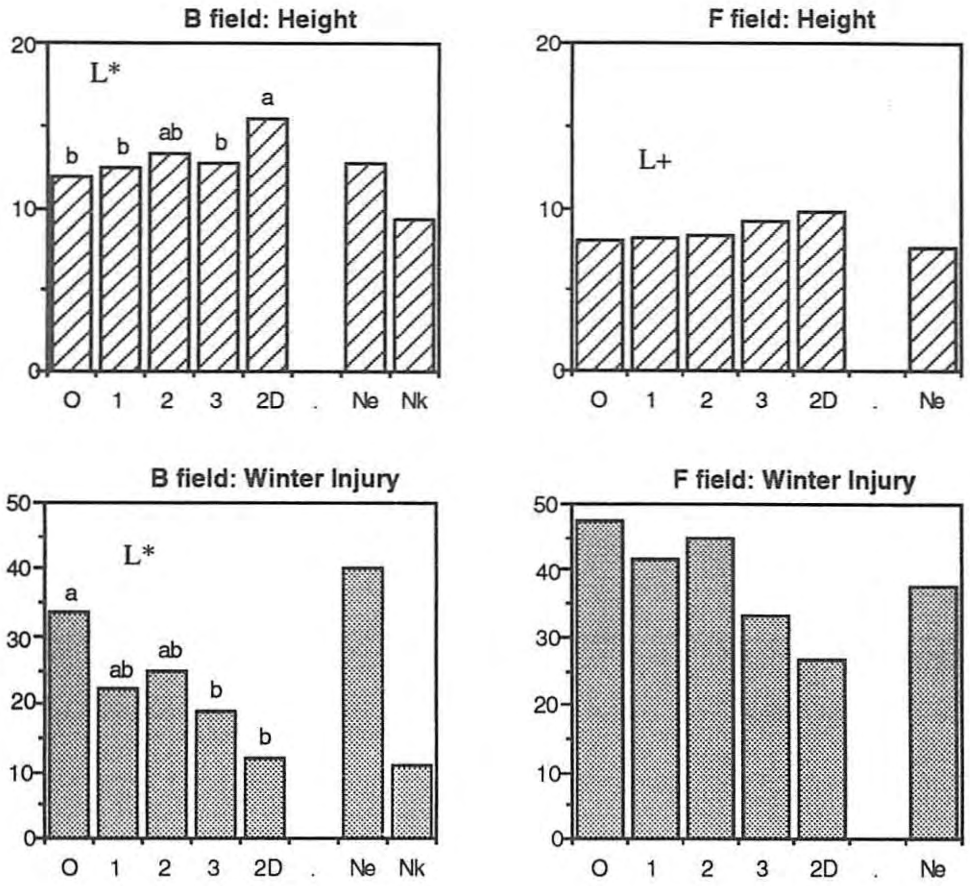


Figure D1. Grass height (in cm) and winter injury (in %) on B and F fields on May 17, 1993 (averaged for all main plots).

B Field (Split-plot)

Height
MP (2,4) F=0.70, p=0.547
Sp (4,51) F=3.43, p=0.015
MP*Sp (8,51) F=0.72, p=0.669

cv MP = 36.8%
cv Sp, MP*Sp = 41.8%

Winter Injury
MP (2,4) F=1.61, p=0.307
Sp (4,51) F=2.43, p=0.059
MP*Sp (8,51) F=0.59, p=0.773

cv MP = 94.5%
cv Sp, MP*Sp = 82.8%

F Field (RCB)

Height
Sp (4,17) F=2.29, p=0.102

cv Sp = 11.5%

Winter Injury
Sp (4,17) F=1.66, p=0.206

cv Sp = 34.9%

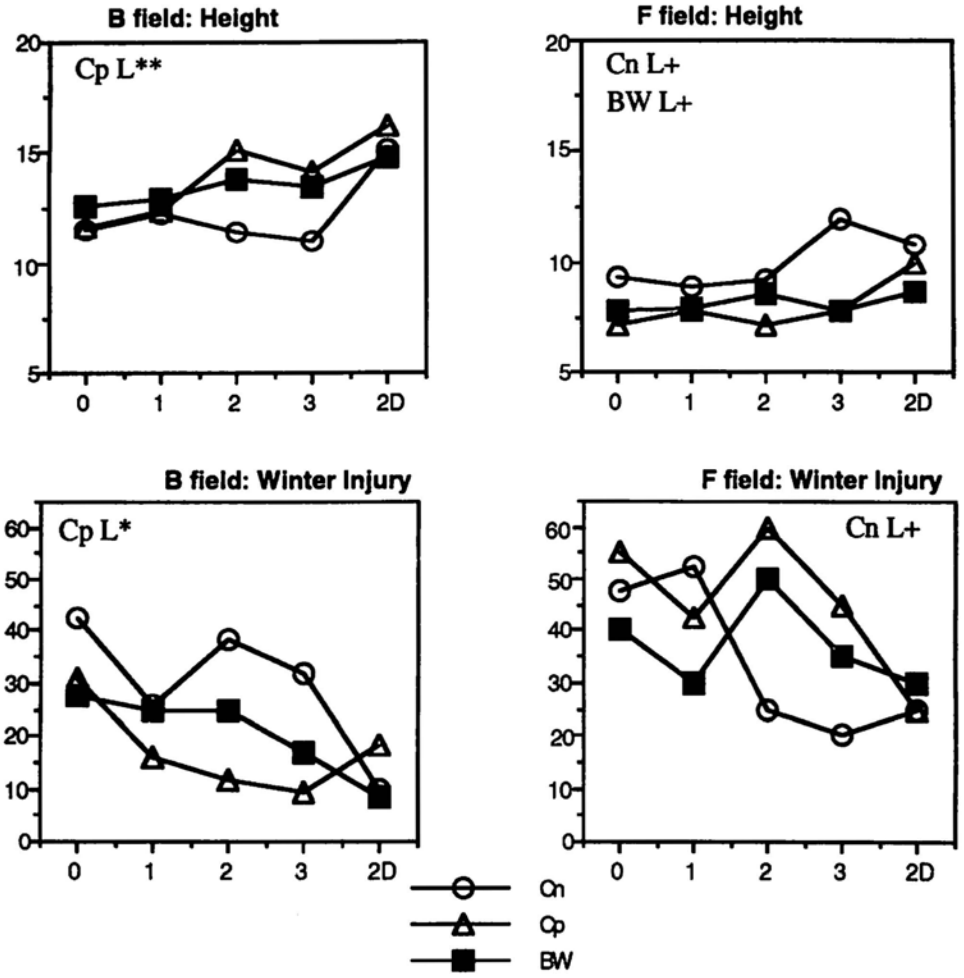


Figure D2. Grass height (in cm) and winter injury (in %) on B and F fields on May 17, 1993 (for different main plot - subplot combinations).

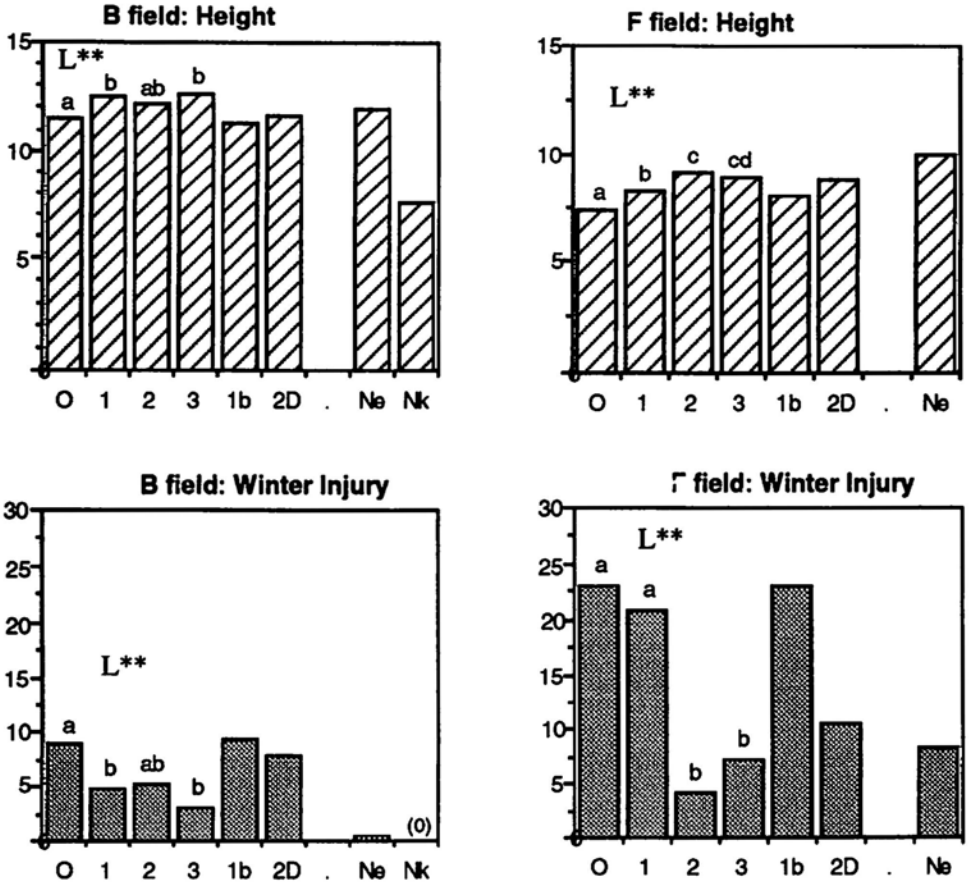


Figure D3. Grass height (in cm) and winter injury (in %) on B and F fields on April 28, 1994 (averaged for all main plots).

B Field (Split-plot)

Height
MP (2,4) F=3.88, p=0.115
Sp (3,36) F=4.26, p=0.011
MP*Sp (6,36) F=0.77, p=0.598

cv MP = 10.2%
cv Sp, MP*Sp = 8.1%

Winter Injury
MP (2,4) F=1.85, p=0.269
Sp (3,36) F=4.56, p=0.008
MP*Sp (6,36) F=1.12, p=0.368

cv MP = 201%
cv Sp, MP*Sp = 88.6%

F Field (RCB)

Height
Sp (3,12) F=19.5, p=0.0001

cv Sp = 4.7%

Winter Injury
Sp (3,12) F=14.5, p=0.0003

cv Sp = 37.6%

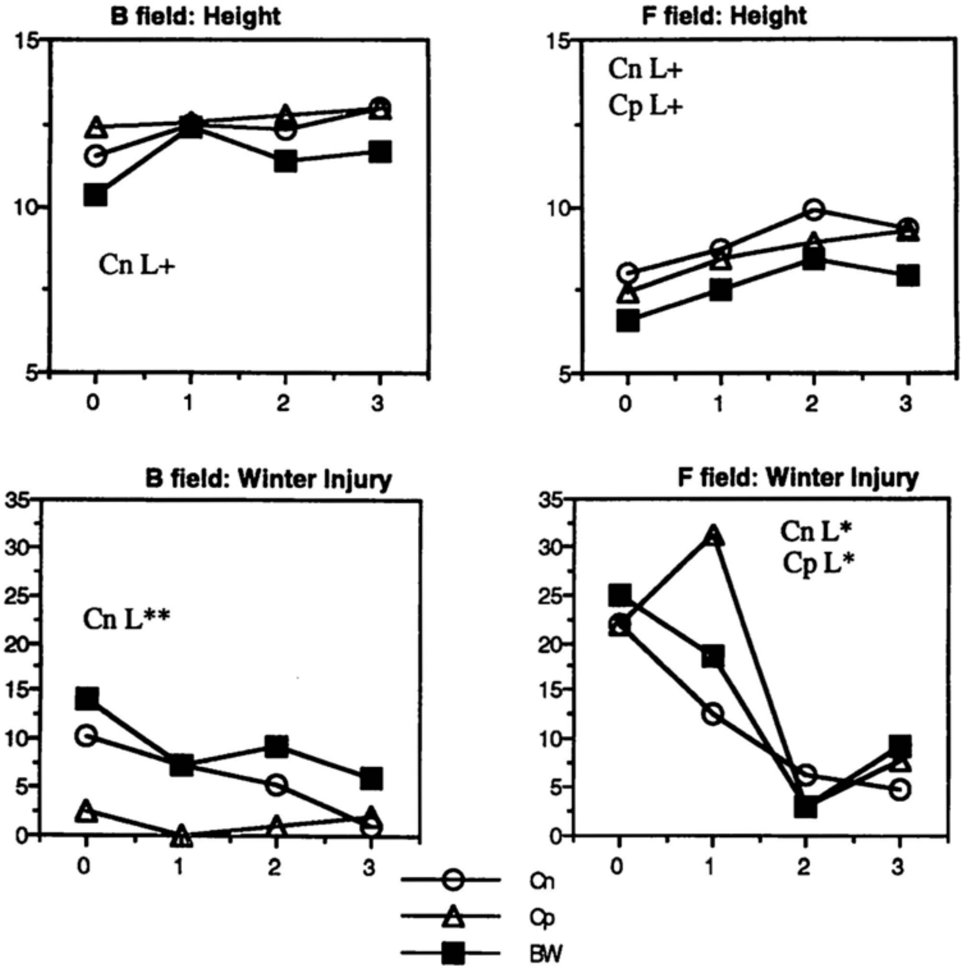


Figure D4. Grass height (in cm) and winter injury (in %) on B and F fields on April 28, 1994 (for different main plot - subplot combinations).

E. Thatch and rooting depth

Thatch is "a loose, intermingled layer of dead and living shoots, stems, and roots that develops between the zone of green vegetation and the soil surface" (Daniel and Freeborg, 1987). Thatch consists predominately of lignin rich materials such as old stems and roots that are slow to decompose. Thatch causes or contributes to disease and pest problems, thinning of the stand, and winter injury. Thatch can become sufficiently dense to significantly reduce water infiltration. Primary factors contributing to its accumulation are heavy clay soils, frequent watering, heavy N fertilizer applications, and grass species or cultivars. Generally, 12.5 mm (1/2 inch) of thatch is considered acceptable, above that, dethatching by manual or mechanical operations is advised. Thatch thickness increases when the rate of production of thatchy materials exceeds its rate of decomposition, thus preventative measures emphasize maintaining a balanced environment for decomposition (Vengris, 1973; Daniel and Freeborg, 1987).

Root growth in turfs has been studied mostly in relation to compaction. Compaction tends to increase surface rooting and decrease deep rooting, but at high compaction surface rooting is also reduced. These changes are related to reduced aeration rather than increase mechanical impedance (Carrow and Petrovic, 1992).

A dethatching operation using a Ryan Ren-O-Thin was conducted on the F field on May 11, 1993, and on the B field on May 27 to aid in removal of debris from the extensive winter injury, prior to overseeding.

The depth of thatch, and of most prolific root growth were documented on June 11-14, 1993, and in the latter half of October, 1994.

Methods

Soil coring tubes (diameter 2.0 cm) were inserted into the soil to 15 cm or less. The top of the cores were removed via the core tube window, and depth of thatch measured with a ruler (Photo 12d). Then the core was held vertically and manipulated gently. The depth of the resulting horizontal fracture of the core - corresponding to a point where root proliferation was insufficient to hold it together - was recorded.

Results

- There were no statistically significant differences ($\alpha = 0.05$) associated with fertility treatments for rooting depth or thatch in either year (Figs. E1-E4), except for a reduction in thatch on the B field in 1993 for the dormant fertilized (OF2D) treatments compared to the corresponding September fertilized (OF2) treatments (Fig. E2). Nor were there any significant linear or quadratic trends.

- In 1993, thatch was thicker on the F than on the B field, and on the F field thatch exceeded the critical thickness (12.5 mm or 0.5 inch), even after dethatching on May 11 (Fig E2).

- In 1994, thatch thickness on both fields was reduced compared to 1993; the decrease was approximately 5 mm on the B field, and 10 mm on the F field (Fig. E5). As no dethatching operations were carried out in the interim, and the verdure increased, the decrease can be attributed to enhanced microbial breakdown of thatch on both fields.

- In 1993, rooting depth was greater on the F field than on the B field overall by about 1.0 to 1.5 cm, however, the rooting depth on Block 3 was equivalent to that on the F field. Rooting depth on the B field increased by approximately 2.5 cm between 1993 and 1994, while it decreased by about 1 cm on the F field (Fig. E5).

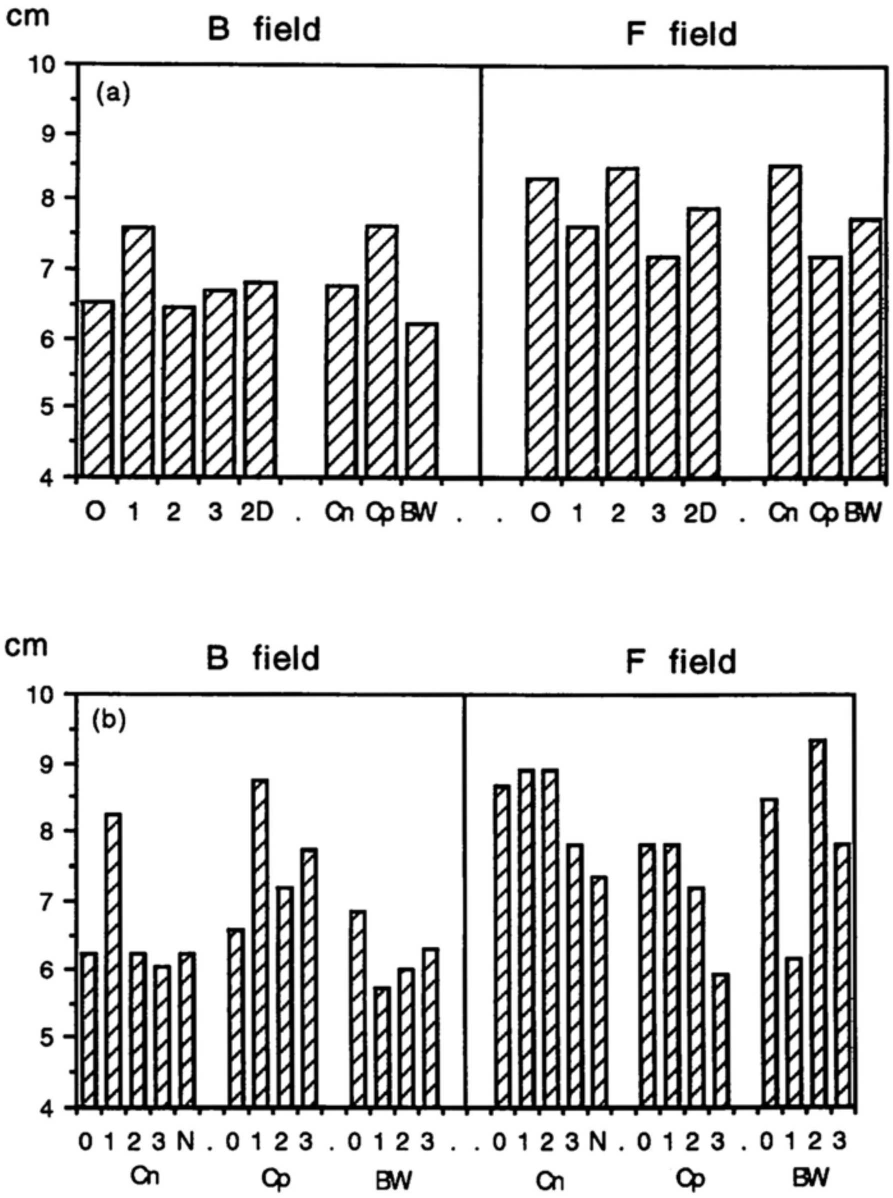


Figure E1. Rooting depth in 1993.

B Field ANOVA (Split plot)
MP F (2,4): 0.1.02, p=0.436
MP * Sp F (6,45): 0.72, p=0.632
cv MP = 43.4%

Sp F (3,45): 0.74, p=0.536
cv Sp, MP * Sp = 35.4%

F Field ANOVA (RCB)
Sp F (3,15): 1.79, p=0.476
cv Sp = 18.1%

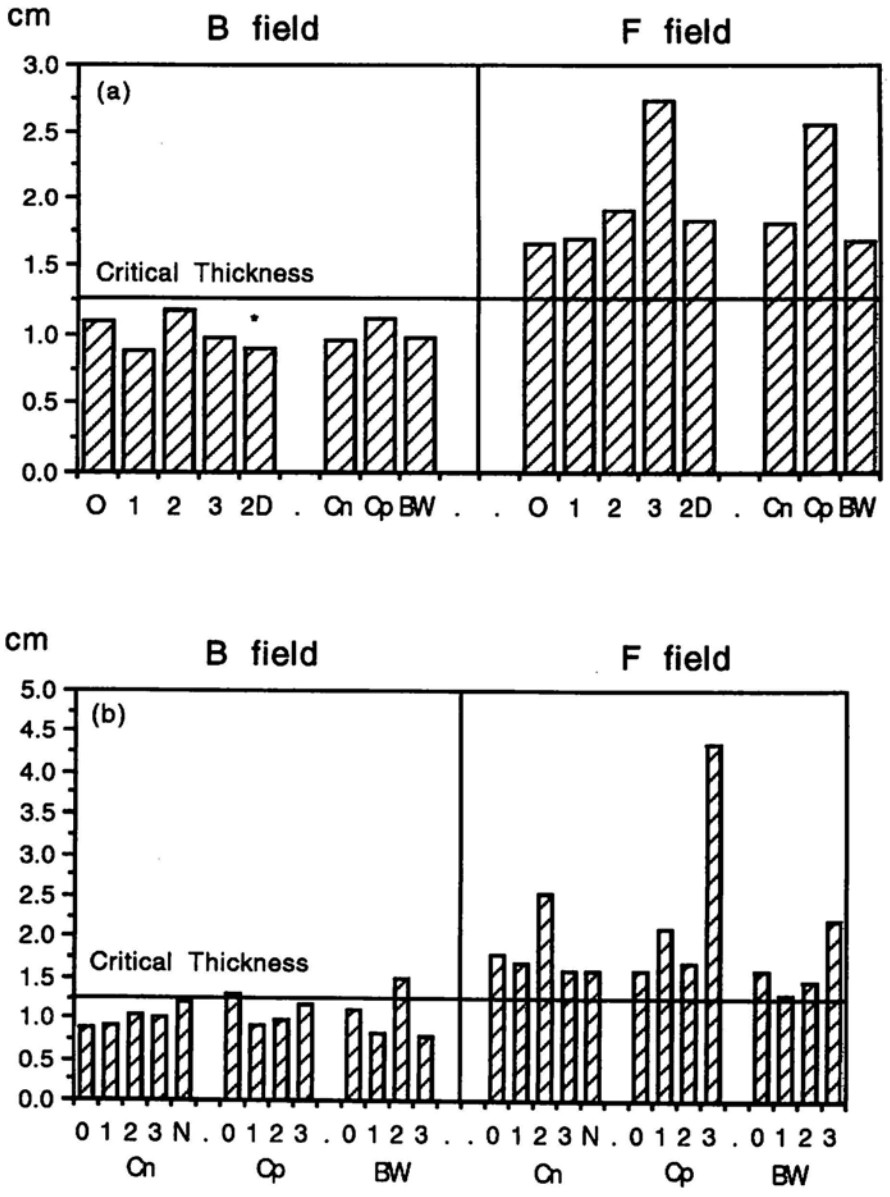
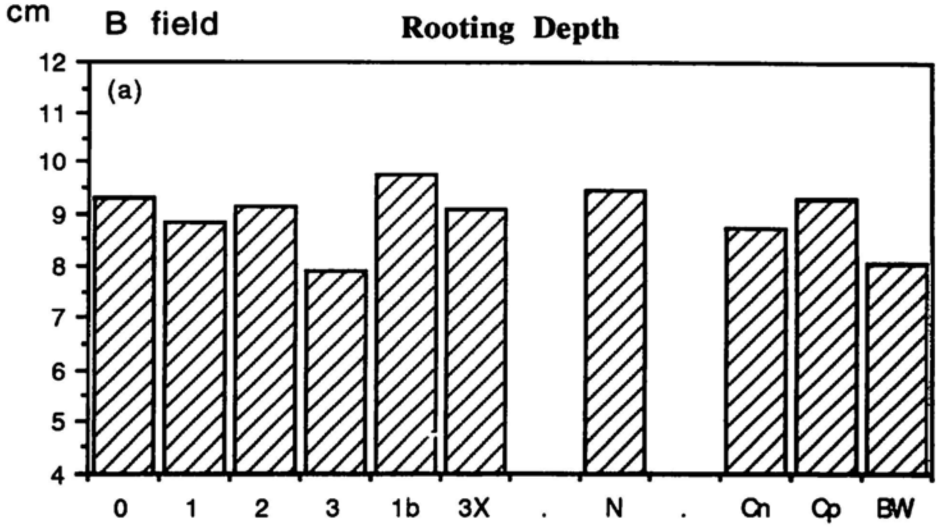


Figure E2. Thatch thickness in 1993.

B Field ANOVA (Split plot)
MP F (2,4): 0.38, p=0.706
MP * Sp F (6,45): 0.70, p=0.651
cv MP = 48.3%

Sp F (3,45): 0.79 p=0.507
cv Sp, MP * Sp = 51.4%

F Field ANOVA (RCB)
Sp F (3,15): 0.76, p=0.534
cv Sp = 69.4%



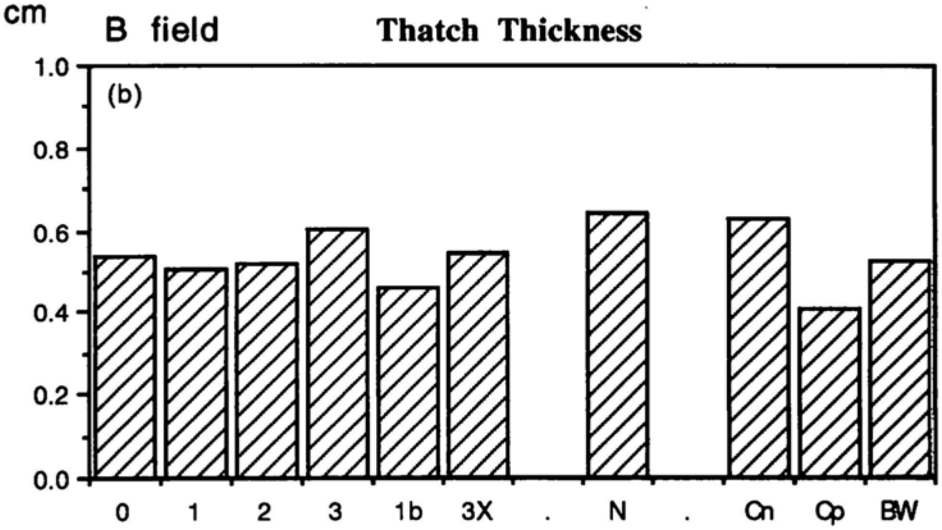
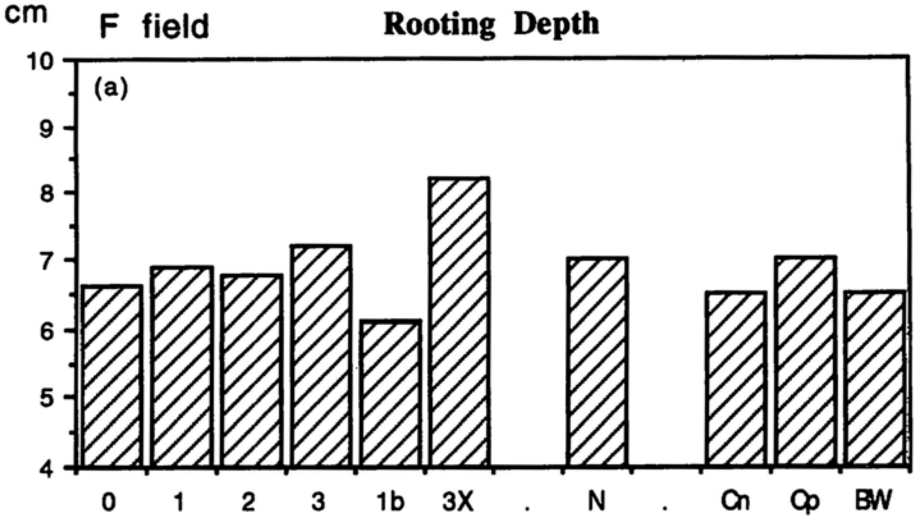


Figure E3. Rooting depth and thatch thickness on the B field in 1994. Data are for organofertilizer subplots from Cn main plots only.

B Field ANOVA (RCB)- Root
Sp F (3,12): 0.75, p=0.541
cv Sp = 15.7%

B Field ANOVA (RCB)- Thatch
Sp F (3,12): 0.29, p=0.832
cv Sp = 26.4%



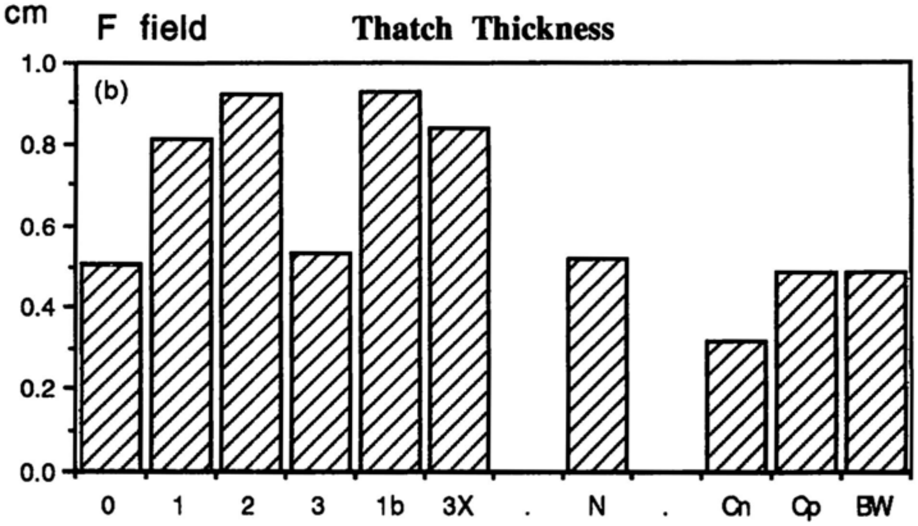


Figure E4. Rooting depth and thatch thickness on the F field in 1994. Data are for OF subplots from Cn main plot only.

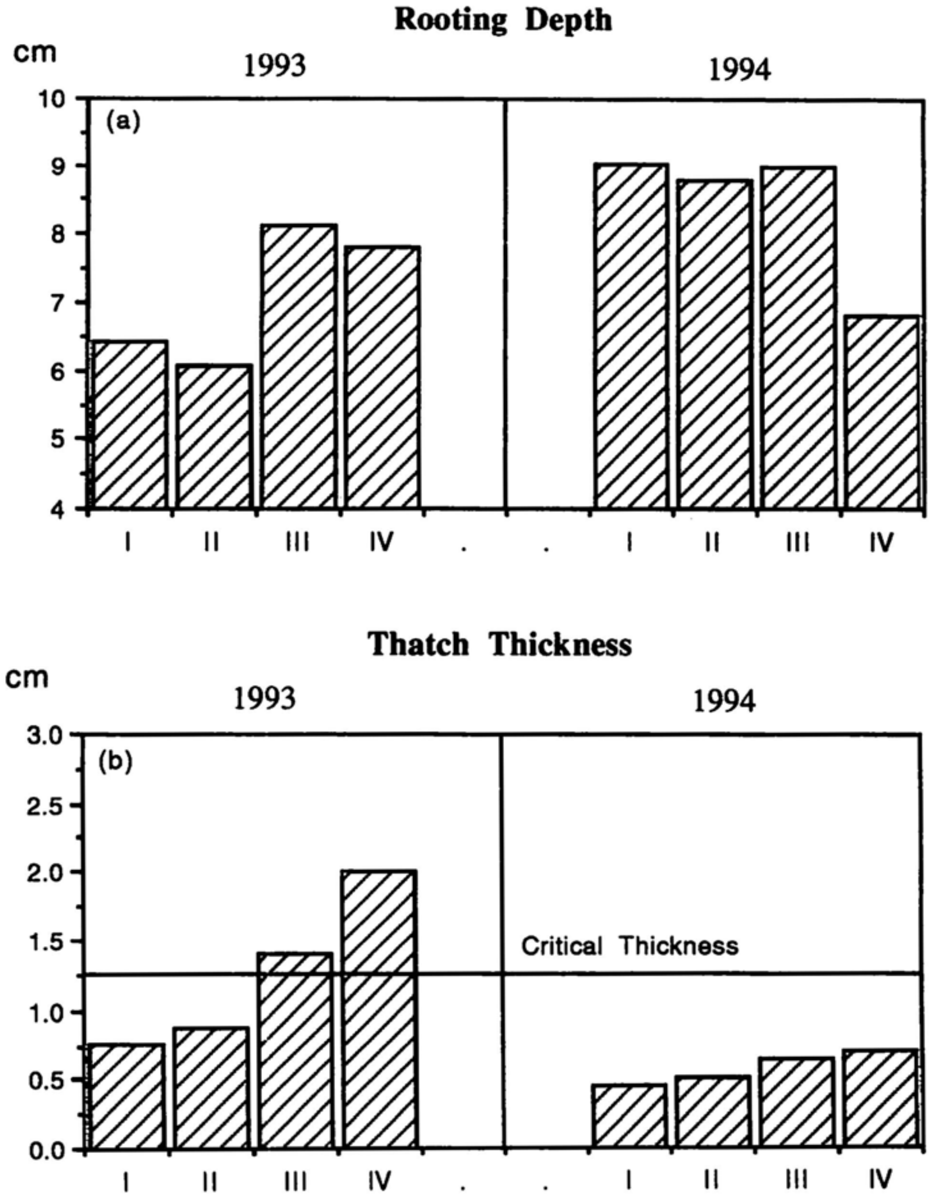


Figure E5. Rooting depth and thatch thickness by Block for 1993 and 1994.

<u>1993 ANOVA (RCB)- Root</u>
Sp F (3,80): 4.41, p=0.006
cv Sp = 31.4%

<u>1994 ANOVA (RCB)- Root</u>
Sp F (3,20): 5.00, p=0.009
cv Sp = 13.9%

<u>1993 ANOVA (RCB)- Thatch</u>
Sp F (3,80): 10.5, p=0.0001
cv Sp = 63.9%

<u>1994 ANOVA (RCB)- Thatch</u>
Sp F (3,20): 3.58, p=0.032
cv Sp = 27.6%

F. Diseases and pests

We anticipated that certain pests and diseases would appear at The Oaks. Pests and diseases are well known to be affected by fertility factors, in some cases intensity decreasing with increasing fertility, in others, increasing or showing a true optimum type of response with lowest or highest values at intermediate fertility. Thus we expected that pests and diseases might invade or infect the different fertility plots differently. The original B field turf had been decimated by chinch bug, and we observed chinch bug in the SW corner of the field in 1993 and 1994, but it did not cause significant damage there, nor did it spread elsewhere. Other insect pests observed on the site included lawn moths/sod webworm, and crane fly, however, like chinch bug, they did not exact significant damage. No diseases were active in 1992. In 1993 and 1994, however, several diseases appeared. Possible relationship of onset and spread of the diseases to climatic conditions is discussed in Section VII-Appendix 1.

Red thread

Red thread was the only turfgrass disease that developed to serious and chronically high levels at The Oaks. The disease was first observed in July of 1993. It's distribution was documented in detail on August 9, November 17, December 21, 1993; April 28, July 11-14, 1994, and in Blocks 1 and 4 only in November 1994.

Percent red thread was calculated from data on the presence and absence of red thread in each of 16 squares within a 50 x 50 cm quadrat placed in the center of each subplot, or in grass only and grass + clover areas within plots.

Distribution in mid-summer of 1993 and 1994

Major points of observation are as follows (see Fig. F1 for 1993 and Fig. F2 for 1994):

- In both years, red thread was abundant on the F field, but was present in much lower levels (1993) or was rare (1994) on the B field.

- On the F field in both 1993 and 1994, highest average levels of red thread occurred on the Cn main plot (compared to other main plots).

- On the F field in both years, increasing levels of organofertilizer reduced the frequency of red thread except for the Cn main plot in 1994. The overall abundance of red thread on the Cn main plot in 1994 was approximately twice that in 1993.

BOX 6: Diseases of turfgrasses as observed at The Oaks.

Red thread

Scientific name: *Laetisaria funciformis*

Host species

-All cool-season turfgrasses, particularly perennial ryegrass and fine leaf fescues.

Conditions

-This fungal disease is typically present in the spring and fall on slow growing, nitrogen deficient turf, but it can occur year-round.

-The disease grows rapidly in prolonged cool, moist weather - heavy dews, light rains, and fog.

-Similar fungal strains with different temperature optima for outbreak of the disease appear to occur (0-30 °C).

-The more favorable conditions for an outbreak include slow growing turf resulting from low temperatures, poor fertility, drought, application of growth regulators, or even stresses caused by other diseases.

-This disease tends to be most severe when potassium, phosphorous, calcium, and especially nitrogen are deficient.

Description / life cycle

-The disease overwinters as mycelium or hyphal mats in diseased or dead plant tissue. Active growth may appear in the spring.

-The infection usually increases in early summer, suffers a set back in mid-summer because of heat and drought stress, and increases again in the favorable conditions of the fall.

-Red thread can be identified as reddish-brown patches of 5 to 35 cm. in diameter. Patches will contain some green grass and the infected tissue will first appear water soaked and straw coloured.

-Under ideal conditions (i.e. humid, moist, cool), advanced infections will result in strands of pink-red fungal hyphae and/or clumps of pink stroma producing spores on the leaf blades.

-Red thread will rarely result in conditions in which fungicide spraying would be necessary. The disease is primarily controlled through application of nitrogen fertilizers.

Leaf spot

Scientific name: Septoria spp.

Host species

-All cool season turfgrasses particularly Kentucky bluegrass. Perennial ryegrass and fine leaf fescues are also susceptible.

-Very little is known or documented on turf species resistance.

Conditions

-This disease is seasonally common in the spring and fall yet it seldom causes extensive damage.

-Infection will occur during cool weather after prolonged periods of leaf wetness greater than 10 hours, and moderate temperatures, 12 °C - 18 °C.

-The disease tends to become dormant below 10 °C.

-This pathogen has been linked to nitrogen deficient turf and soils which have been treated with growth regulators.

Description / life cycle

-This fungus survives the winter and summer as mycelium in diseased leaf tissue, thatch, organic debris, or in the soil.

-Spores are produced during cool, wet periods and infect tissue with the free movement of excess water in the canopy.

-Small lesions occur in spots, stripes or blotches near the leaf tips.

-Lesions can vary in color from gray/green to light to deep brown and sometimes purple.

-Lesions enlarge and typically fade to a straw color with time.

-Extensive infections can result in a turf stand taking on a "scorched" appearance, regardless of the damp cool weather.

Note

Typically and more commonly, Leaf spot infections of turfgrass species tend to be a Leaf spot pathogen formerly identified as *Helminthosporium*. This disease has since been re-classified into three particular groups listed below. During the course of the experiments at The Oaks, although not formerly confirmed by laboratory analysis, minor outbreaks, of what classically presented itself as *Helminthosporium* (*Drechslera*) were observed and as such a description of these types of Leaf spot has been provided below.

Scientific name: *Helminthosporium* spp. (formerly) - root, stem, and crown rot.

Reclassified as:

Drechslera; particularly *D. poae.*

Bipolaris; particularly *B. sorokiniana*
and *Curvularia*

Host species

- All cool-season turfgrass species particularly Kentucky bluegrass.

- Many new varieties of Kentucky bluegrass are very resistant.

Conditions

- Leaf spot diseases generally occur between spring and late autumn.

- Severe infections can occur in early to mid summer.

- Leaf spot infections can occur at temperatures ranging from 3 - 27 °C.

- Long periods of leaf wetness, greater than 10 hours, arising from various conditions will enhance disease development.

- This disease tends to be more severe on turf grown under excessive fertility.

- Leaf spot symptoms and infections are enhanced by drought stress.

Description / life cycle

- These disease fungi survive winter in diseased and dead tissue, organic debris, thatch or soil as mycelium.

- In the spring, active growth produces spores which are carried to the leaf surfaces in the presence of free water movement in the turf canopy.

- Infections initiate as small brown/black areas on the leaves. With development they expand and create lesions with straw colored centers and brown/black margins. These lesions can coalesce to blight the entire leaf.

- Plant sheaths and crowns are also susceptible and infection can result in serious damage. This phase of the disease is referred to as "melting out" of the turf.

Pink snow mold

Scientific name: Fusarium nivale

Host species

-All cool season turfgrasses particularly annual bluegrass, perennial ryegrass and creeping bentgrass.

-Kentucky bluegrass and fine leaved fescues are less susceptible.

-"Pink snow mold" is the term used to describe this particular manifestation of the fusarium pathogen which is associated with spring snow melt.

Conditions

-This disease occurs on turf under moist, snow covered, unfrozen soils during the winter/spring season.

-The infection can occur with as little as 12 days of snow cover with temperatures in the -1 °C to -4 °C.

-Poor drainage and long matted grass blades over the winter promotes infection.

-High nitrogen fertility throughout or late in the fall, resulting in over succulent growth prior to winter dormancy raises susceptibility.

-This disease is also linked to heavy, thatchy turf growing very slowly.

-Lower pH soils and adequate levels of potassium maintained through the fall tend to suppress the disease.

Description / life cycle

-The pathogen survives the summer period as spores and mycelium in thatch, organic debris, or in the soil.

-This disease can occur under prolonged as well as relatively short periods of snow cover (12 - 90 days).

-Under favorable conditions, mycelia grow from infected debris and inoculate healthy tissue.

-As snow melts, 5 - 20 cm bleached, circular patches (mycelium matted grass) become exposed. Patches can be orange/brown to gray in color at this time.

-White to pink mycelium can often be seen on the outer margins of patches and these patches can overlap and join to form larger irregular patches.

-As the damp, matted, grass patches dry in the sunlight they tend to become reddish/brown and the grass becomes brittle.

-With Kentucky and annual bluegrass, patches tend to be white in the center and reddish/brown towards the outer edge.

-This disease tends to be very persistent in localized areas year after year as long as conditions remain favorable for the pathogen.

Anthracnose

Scientific name: Colletotrichum graminicola

Host species

-All cool season turfgrasses, particularly annual bluegrass.

-Perennial ryegrass is less susceptible.

-Many currently available turfgrass species and varieties are very tolerant to anthracnose.

Conditions

-Occurs typically June to September under prolonged warm and humid conditions.

-Several days over 26 °C with long periods of leaf and canopy moisture/humidity promotes infection.

-Tends to occur in conjunction with drought stress, fertility stress - low K, low P, low N and/or compaction.

-Light sandy soils tend to be more susceptible than heavy clay soils due to moisture retentive properties.

Description / life cycle

-This disease is described as a "weak" pathogen that survives perennially in the damage when turf stands are under stress.

-Under active growth, spores are produced and are splashed onto the foliage with free water movement in the canopy.

-The fungus can infect turf and cause leaf yellowing in cool weather but real damage and death of plants generally result from hot/humid infections due to the presence of greater stresses.

-Lesions on leaves can coalesce and result in irregular and complete blighting of leaves. This can further result in a turf stand taking on a bronze/brown to tan appearance from a distance. The main diagnostic feature of the disease appears quite late in the development. Dark fruiting bodies (acervuli), with hair like structures (setae) protruding from them, appear on the blighted and dead leaves. They can be seen with the assistance of a hand lens (10X).

Sources used in the disease descriptions included:

(1) Olkowski, et.al., (1994).

(2) OMAF, 1993.

(3) OMAF, 1981.

(4) Smiley, et.al., (1992)

BOX 7: Insects of turfgrasses as observed at The Oaks.

Hairy chinch bug

Scientific Name: Blissus leucopterus hirtus Montandon

Description

The hairy chinch bug has been described as "*perhaps the most devastating of all turf insects...[it] will reach population levels that can kill off extensive areas of turf in a matter of a few days*" (Decker, 1988, Photo 1b). Decker, (1988) describes the sudden damage as, "*a perplexing problem to the turf manager. On a typical suburban street some of the lawns will show extensive damage in what is almost a random pattern down the block. Many of the lawns will be completely spared, showing little or no damage. Given the same weather and the same general population, obviously some factor difficult to detect protects some lawns, which often show a marked boundary between the damaged and the protected ones*". There are a lot of research reports on factors affecting chinch bug; put together, they illustrate that the chinch bug problem is largely one created by intensive chemical management practices, especially on turfs of Kentucky bluegrass heavily fertilized with N.

Kentucky bluegrass generally requires high levels of N fertilizer for good spring greening up and sustained quality throughout the growing season. Heavy applications of N fertilizer tends to induce quick, lush and succulent growth which increases the grasses susceptibility to a variety of pests. The heavy use of N also increases drought susceptibility, and turfgrass is more susceptible to chinch bug when it is drought stressed. In response, irrigation becomes necessary, but irrigation combined with high N availability tends to encourage fungal infestations. The use of large amounts of N alone encourages fungal growth on grasses, so fungicides are employed to reestablish control. This results in a situation where as well as killing the deleterious fungi, the fungicides also kill a known fungus which is parasitic on the chinch bug. When pesticides are utilized to eliminate a chinch bug problem, existing natural insect enemies, both predatory and parasitic, are also killed due to the inherent non-selectivity of the insecticides employed.

Kentucky bluegrass is known to be a considerable thatch accumulator in relation to other cool season turfgrass species and particularly when maintained under an intensive N fertility regime. Thatchy turf provides both a protective environment and a substantial food source encouraging chinch bug infestation. The use of synthetic chemicals and pesticides increases the mortality of critical soil borne micro and macro fauna and flora necessary for the continually natural and steady breakdown of thatch. It becomes clearer that starting with Kentucky bluegrass and N fertilization, addictive and unstable types of processes are established and entrenched, that in fact, encourage chinch bug - resulting in a situation where chemical control becomes "necessary".

In organic management, the chinch bug problem is dealt with by reestablishing natural balances which prevent it from becoming a problem. For severely affected turfs, some use of biological pesticides may be necessary when the turf is in transition from conventional chemical management to an organic management regime. The Edmonds' experience indicates that a program of dethatching, hollow tine core aeration and organic fertilization are usually sufficient to bring the chinch bug and other common pests under control during the transition to organic management. With time, alternate species of grass blend with the existing stand, natural controls are reestablished and promoted, soil structure improves and there is a more balanced release of nutrients, all of which bring chinch bug, and most other pests -firmly under control.

Sod webworm / lawn moths

Scientific name: Crambus spp. and *pediasia* spp.

Description

During the summer season of 1993, noticeable and significant numbers of adult lawn moths were observed during regular maintenance of the research plots at The Oaks. Larger populations being observed on the B field as compared to the F field. The potential presence of a substantial webworm larvae population was suspected due to the observed flight activity. However, no visible or obvious damage was apparent or attributable to the observed activity.

European crane fly

Scientific name: Tipula paludosa Meigen

Description

In the late fall of the 1994 season, small but noticeable numbers of late afternoon flights of European crane fly were observed. Visible populations of adults seemed minor in relation to the total area of the research plots. Again, no visible or obvious turfgrass damage was apparent or attributable to the observed flights in either the spring of 1994 or, in the more likely, spring of 1995.

Sources used in the insect descriptions included:

(1) Decker, (1966).

(2) Davis and Smitey, (1990).

(3) Potter et.al., (1985).

(4) Tashiro, (1987).

(5) Olkowski et.al., (1991).

- On the F field, bag mowing increased the frequency of red thread in 1993 while in 1994 it reduced it (Treatment 1 vs 1b in Figs. F1, F2).

- In 1993, relatively high levels of red thread occurred on the NPK main plots on both the F and B fields. In 1994, however, NPK main plots had no red thread infection.

- In 1993, within the NPK-Ecomix subplots red thread was observed almost exclusively on Kentucky bluegrass. In 1994, red thread was still more abundant on Kentucky bluegrass than on other species although the disease was also present on perennial ryegrass and the fescues.

- In 1994, data were collected from minus clover and plus clover quadrats placed in each plot or subplot which allowed us to examine the effect of clover on red thread (Figure F2). For all treatments, the frequency of red thread infection was 29.1% in minus clover subplots and 12.3% in plus clover subplots (p=0.052).

Distribution in the fall of 1993 and 1994

After retreating considerably in the early fall, red thread began to proliferate in the late fall of 1993. Presence or absence of red thread on subplots was recorded on November 17 just before the application of dormant fall fertilizer. On December 21, presence and absence was again noted, and the number and size of individual patches was documented (Fig. F3; Tables F1, F2). We noted:

- Overall, there was a trend for reduced abundance at higher levels of organofertilizer except on the BW main plot on the B field and the Cn main plot on the F field.

- Red thread was less abundant on bag mowed plots than on the equivalent mulch mowed plots (but differences were not statistically significant).

- On one of the two OF2 subplots (OF2f in Table), Biostar, a liquid fish silage product shown in other studies to have some fungistatic properties was applied in place of the organofertilizer. Although not statistically significant, the data suggest that Biostar reduced the spread of the red thread between Nov. 17 and Dec. 21. Biostar also reduced red thread incidence compared to the equivalent level of organofertilizer (compare OF2 versus OF2f in Fig. F3a,b).

In the fall of 1994, red thread declined to almost zero abundance on the F field, but became very abundant on the B field (Table F2). This was in marked contrast from previous trends.

The very low abundance of red thread on the F field may have been associated with grass on that field going into dormancy early in the fall of 1994 in comparison to the B field (Section III.1H). The grass on the F field also was dark green in late fall (Section III.1B) which we attribute to high N accumulated during the previously extended dry weather period of October.

Distribution in spring 1994

Data on red thread distribution was again collected in late April of 1994. Frequency of red thread was determined as the presence and absence of red thread in each of 16 squares within a 50 x 50 cm quadrat placed in the center of each subplot. Major points of observation are as follows (see Fig. F4):

- The benefit of the Biostar fish silage product in reducing red thread incidence, documented in the fall of 1993 (Fig. F3a,b) was not sustained in the spring of 1994 (OF2f in Fig. F4).
- For the most part on both fields, trends observed in the spring of 1994 were similar to those observed in fall of 1993. The major exception was on the Cn main plot on the F field. In contrast to the fall of 1993, in the spring of 1994 the Cn main plot had the lowest levels of red thread and there was evidence of decreasing red thread with increasing levels of organofertilizer.

Distribution in 1995

No fertilizers were applied to either field in the fall of 1994. In early June of 1995, organofertilizer at 2 lbs N per 1000 sq ft was applied to the F field, and 1 lb N per 1000 sq ft to NPK main plot, and the SW section of the B field (most of Block 3-BW main plot).

- In mid-summer of 1995, the patterns of red thread distribution were similar to those observed in 1994; red thread was very abundant on the F field and was difficult to locate on the B field.

Control measures

The red thread "problem" at The Oaks was mostly an experimental artifact in that we were maintaining some plots under nutrient stressed, and therefore red thread-susceptible conditions. This allowed large inocula to build up. The usual control advised for red thread is N fertilization, but we could not do that without changing the experimental fertility regime. On the other hand, we were concerned that the level of red thread was getting so high that it would overtake most of the plots. Control measures were undertaken that we hoped would reduce the proliferation of red thread, but that would not change the experimental regimes or entail use of materials normally prohibited under organic management. These included:

(i) In August 1993, portions of the F Field main plots outside of the organofertilizer subplots received an application of Biostar fish silage at a rate of approximately 0.5 lb N per 1000 sq ft (stock 1% N, diluted 5 fold).

(ii) The SW corner of the B field, encompassing mostly the Block 3-BW main plot had high levels of red thread in the spring of 1994. This area was peculiar in that it dried out very rapidly and it tended to look poor through most of 1993 and 1994, in comparison to the rest of the B field. In May of 1994, this area was dethatched and raked to remove litter.

(iii) On July 15, 1994, infected areas on the F field were raked out and the entire field was sprayed to the drip point with 3% insecticidal soap solution. Organofertilizer was applied at 1 lb N per 1000 sq ft to main plot turf areas outside the subplots. On the B field, the raking and spraying were conducted on specific patches.

(iv) No fall fertilizers were applied at The Oaks in 1994. In the spring of 1995, organofertilizer was applied at 1.5 lb N per 1000 sq ft to the whole F field, and 1 lb N per 1000 sq ft was applied to the BW main plot, Block 3 of the B field, and to NPK main plots on the B field (which appeared severely nutrient stressed). Another application of organofertilizer (0.5 lb N) was made to the F field in early July, 1995.

Interpretation

Red thread developed initially on the F field. On both fields the infection was highest on the plots of lowest fertility which is consistent with the known patterns of development of this disease. There is good evidence from our observations that clover reduced infection, presumably by improving N nutrition of associated grasses.

Overall, the F field was much more nutrient stressed than the B field, and had very little clover in 1993, in marked contrast to the B field. The F field also suffered much more from drought stress. Until we recognized the presence of red thread, the F field was usually mowed first followed by the B field. Thus it appears that red thread became established on the F field readily once an inoculum came into the site (possibly on mowers) because of the presence of large nutrient stressed areas, lack of clover, and perhaps due to some weakness or metabolic imbalance associated with drought stress. A heavy innoculum transfer then resulted in some infection of the B field even though overall it would probably have otherwise been quite resistant, with the exception of the SW corner. Interestingly, through 1993 and 1994, the areas outside of the main plots on the F field, did not develop red thread. These had all received compost when they were set up, and except for the strip of minus clover mixture plots along the north edge of the field, they also received regular applications of organofertilizer (@ 3 lbs N per 1000 sq ft per year).

In the summer of 1994, organofertilizer seemed to have no effect on red thread on the Cn main plot on the F field, which we attribute to a very high inoculum, verifying the fertility factors that influence red thread.

In the summer 1994, levels of red thread were lower on the B field than they had been in 1993. This could have been due to changing the mowing sequence so that the B field was mowed first, and/or to the overall very healthy status of the B field.

In the late fall, when the B field became naturally stressed, red thread increased as it had in the fall of 1993. Curiously, at the same time it was almost non-existent on the F field, even though it had been very intense there in the summer, and had been abundant in the fall of 1993. The resistance could have been due to early initiation of dormancy of grass in this field in 1994, (Section III.1H) and maintenance of high greenness (Section III.1B) and therefore N (Section III.1I).

In 1995, the summer patterns observed in 1993 and 1994 were again observed, with heavy infection on the F field and almost none on the B field. In 1995, the mowing sequence (taken over by new field personnel) was again from F to B. Thus it seems that the resistance of the B field is attributable to its overall health rather than to a low inoculum factor.

In conclusion, the principal factor that predisposed turf to infection in this system appeared to be N stress in Kentucky bluegrass on the F field. Factors that seemed to have conferred substantial resistance were: presence of clover, mixtures of grass species, compost, and top dressings of organofertilizer. The fish silage product appeared to be effective in short term control. Bag mowing increased susceptibility to initial infection, but once established, reduced incidence of the disease.

Leaf spot diseases on grass

A leaf spot, which appeared from the macroscopic form (Photos 10b,c) to be a *Drechslera* spp. (Smiley, et.al., 1992; OMAF, 1981) was noted in the fall of 1993. A leaf spot was also noted on Kentucky bluegrass in the spring of 1993, however, it dissipated by early summer and was not a factor affecting overall quality of the turf.

In the fall of 1993, Kentucky bluegrass subplots in NPK main plots, and most bag mowed plots were demarcated sharply from surrounding turf by their overall brown appearance (Table F3). Individual plants showed typical leaf spot symptoms, and presence of *Septoria* leaf spot was confirmed by the Plant Industry Branch of NSDAM. Similar patterns were observed in 1994.

Anthracnose on grass

Anthracnose (confirmed by Plant Industry Branch of NSDAM) was first noted as prominent in July of 1994 on a section of the Cn main plot in Block 1 in a protected area adjacent to a snow fence (Photos 12a,b).

On July 11-14 observations on anthracnose were included in the general quality observations conducted in minus and plus clover sub-subplots It was given a rating of 0 to 5, with (0) = none; (1) = 5%; (2) = 5-10%; (3) = 10-20%; (4) 20-30%; (5) >30% of blades with some anthracnose (visually estimated).

Distribution in 1994

- There were no statistically strong effects of the treatments on anthracnose. There were weak trends ($p<0.2$) for differences due to mowing (bag mowed values higher), and withdrawal of fertilizer from the OF3 level in 1994 (OF3X plots had higher scores than OF3 plots).

- There was a trend of higher values in the absence of clover than in its presence (Fig. F5). Analysis of a larger data set which included all treatments on the B field showed only the clover effect to be significant (p=0.0073; the main plot p value for this data set was 0.102; all other p values were >0.4)

Overall, the data suggest a suppressive effect of organofertilizer and clover on anthracnose, and stimulation by bag mowing (i.e., effects were quite similar to those observed for red thread in 1993). Although the disease was noted only on Kentucky bluegrass, it was not more abundant in the Kentucky bluegrass plots than others, which we attribute to the interaction of Kentucky bluegrass with clover, as for red thread. The anthracnose persisted on Kentucky bluegrass until well into October which was unusually warm and dry (Section VII- Appendix 1).

Pink snow mold

Distribution in spring of 1994

- When averaged across all subplots and main plots, the F field had a higher incidence of pink snow mold (0.73%) compared to the B field (0.31%), however, the higher average value on the F field was primarily related to the one extremely high value for the BW-OF3 plot (18.7%) (Fig. F6a,b).

- On the B field, Cp main plot had the lowest average pink snow mold (0.00%) compared to Cn main plot which had the highest value (1.43%).

- On the F field, BW-OF3 plot had the highest level of pink snow mold (Fig. F6d). The remainder of the field was little affected.

Diseases on clover

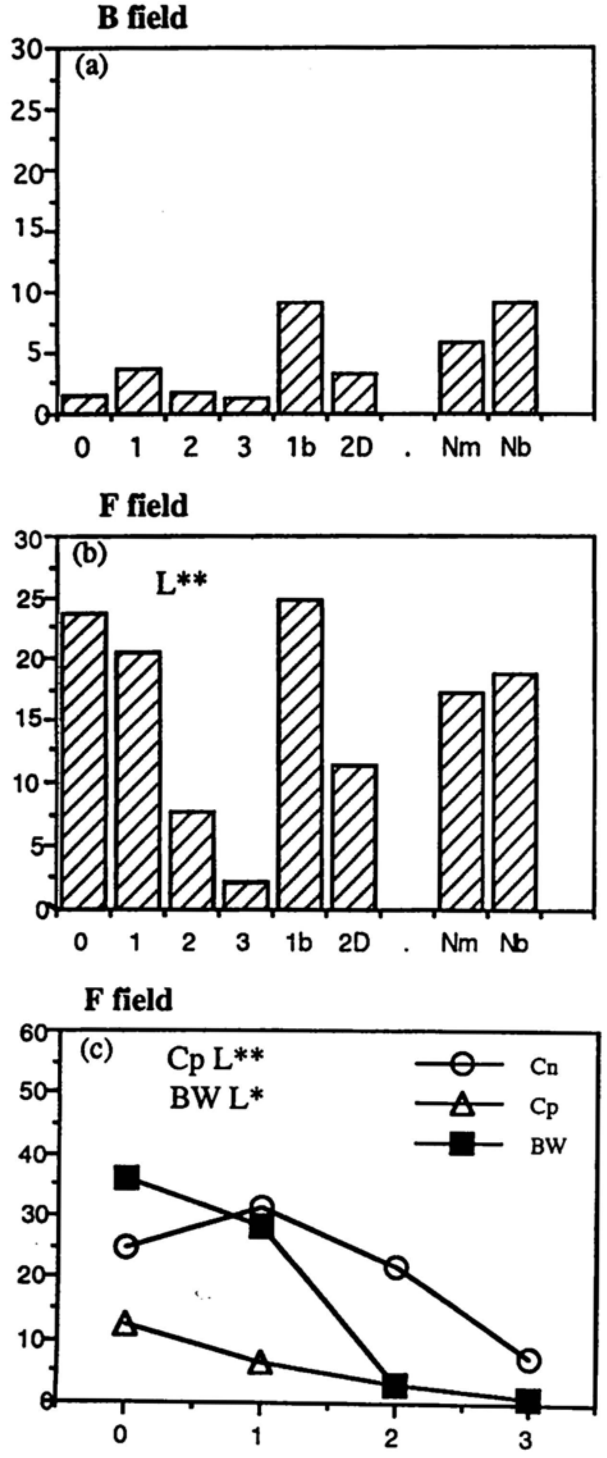
Three categories of patterns of infection of clover by fungi were noted in 1993: "blotch", "spots" and "whole leaf" necrosis (Photo 11d). Disease organisms identified at the Kentville Agricultural Station from samples of the three categories were respectively:

(i) sooty blotch (*Cymadothea trifolii*),
(ii) sooty blotch and unknown leaf spot,
(iii) slime mold.

Frequency data were obtained in August 1993 and July 1994 by recording the number of squares out of 16 within 50 x 50 cm quadrats in which clover was present and numbers of those squares in which the various disease symptoms were present. Percent occurrence of disease symptoms was calculated as (squares with disease)/(squares with clover) x 100. Data were transformed (arcsinsqrt), and subjected to ANOVA as for the red thread data.

- These analyses showed no significant or otherwise pronounced trends between treatments. Average percent occurrence of the three categories in 1993 and 1994 are given in Table F4.

- In July of 1995, sooty blotch was observed on both fields but was rare, and the other two conditions could not be found.



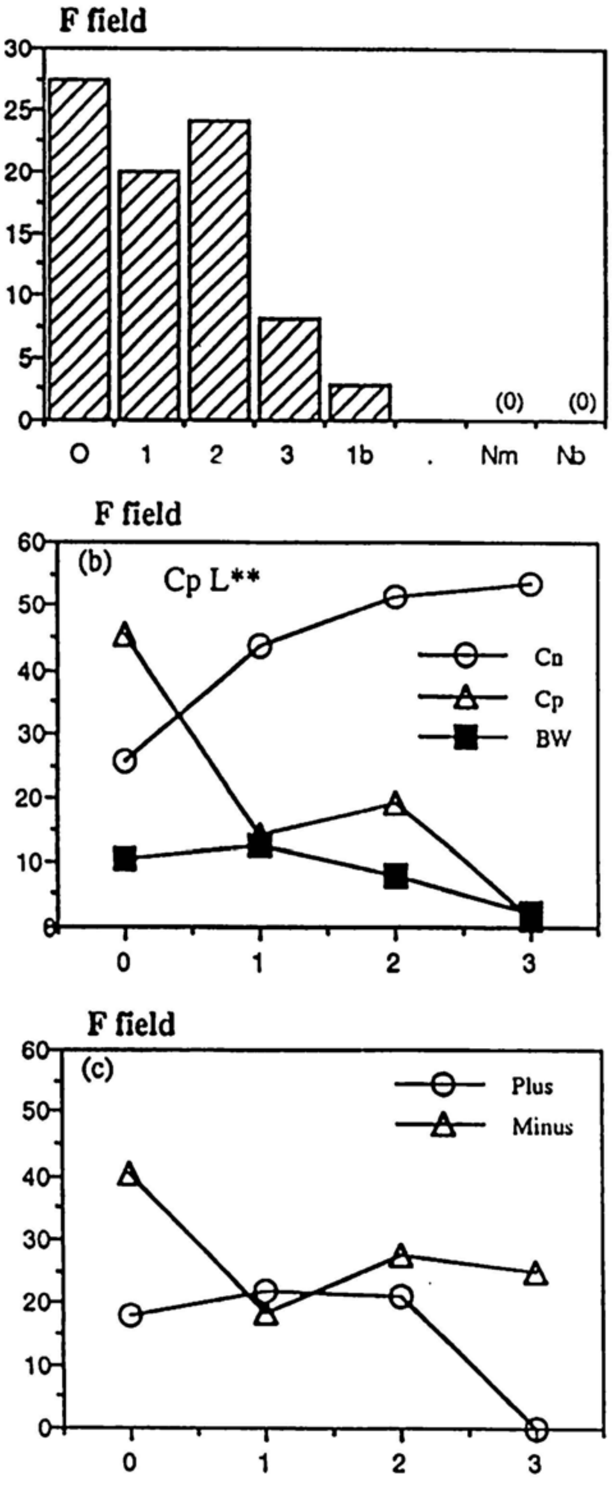
B field (Split-plot)

MP (2,4): F=1.76, p=0.283
Sp (3,36): F=0.95, p=0.428
MP*Sp (6,36): F=1.12, p=0.369
cv MP = 11.8%
cv Sp, MP*Sp = 6.8%

F field (RCB)

Sp (3,12): F=10.9, p=0.001
cv Sp = 4.1%

Figure F1. Percent red thread on August 9, 1993 (a,b) for all main plots, and (c) for OF subplots within each main plot. Statistics conducted on arcsinsqrt transformed data.



F field (Split-plot)

Organofertilizer (3,6): F=0.96, p=0.469
Clover (1,20): F=4.27, p=0.052

Plus clover mean (n=18) = 12.3%
Minus clover mean (n=18) = 29.1%

cv Organofertilizer = 18.0%
cv Clover = 19.2%

Averages For Main Plots:

Cn = 41.5%
Cp = 19.3%
BW = 6.5%

Note:

Differences between OF3 and OF3X, and between OF2 and OF2f were not significant (p=0.1), and OF3X and OF2f plots were considered to be OF3 and OF2 plots respectively. OF1b differed from OF1 (p=0.0973), and was not included.

B field

Red thread present only on:

Block 2: OF0 (1 of the 2 plots)
Block 3: NPK-bag and mulch plots.

Figure F2. Percent red thread in July, 1994, (a) for all main plots, (b) OF subplots within each mainplot, (c) OF subplots averaged for all main plots, plus and minus clover. Statistics conducted on arcsinsqrt transformed data.

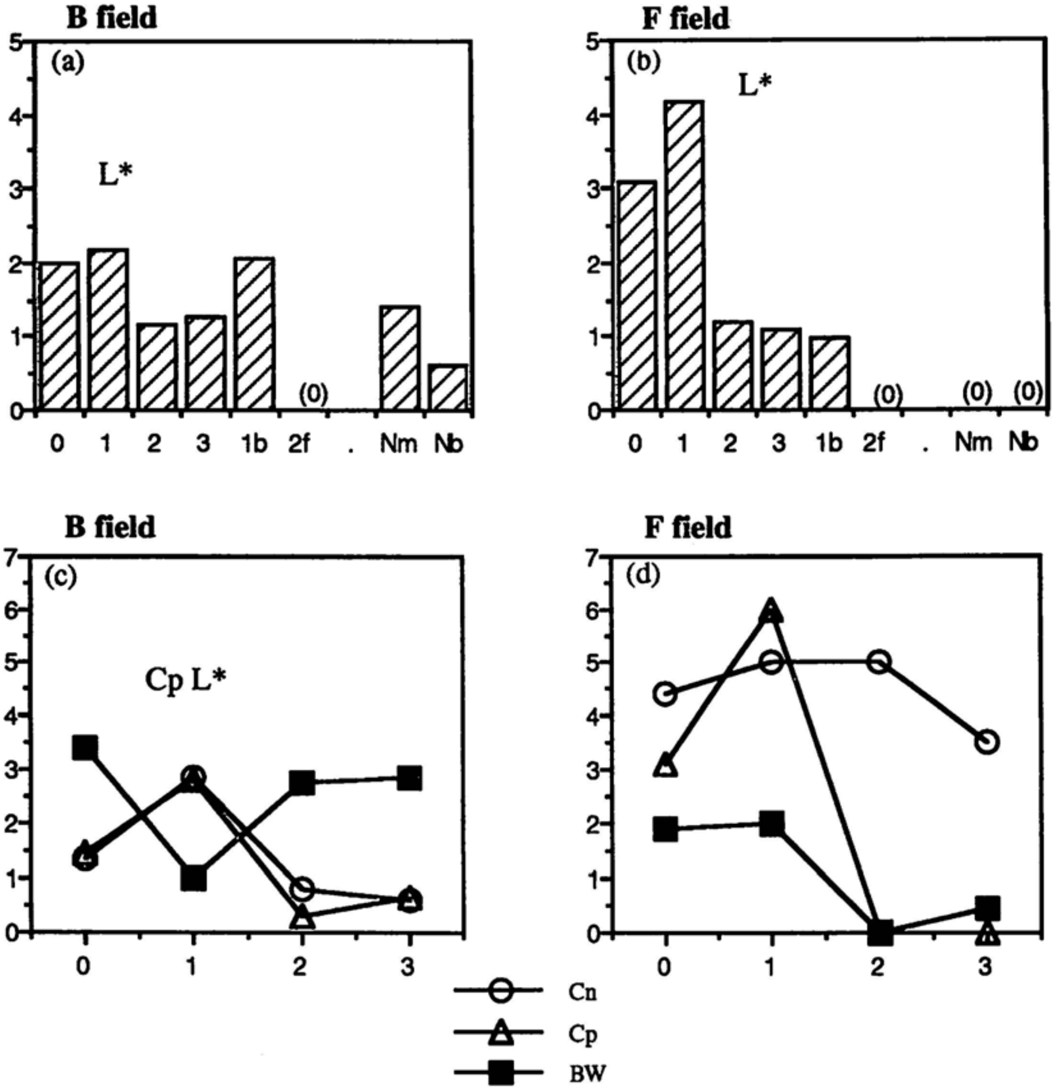


Figure F3. Red thread distribution on December 21, 1993. Values are number of patches per subplot (1.5 m x 1.5 m). Statistical analyses were conducted on $(X + 0.5)^{1/2}$ transformed data.

B field (Split-plot)

MP (2,4): F=0.79, p=0.512
Sp (3,36): F=0.97, p=0.415
MP*Sp (6,36): F=1.30, p=0.281
cv MP = 51.5%
cv Sp, MP*Sp = 33.6%

F field (RCB)

Sp (3,12): F=3.39, p=0.054
cv Sp = 18.8%

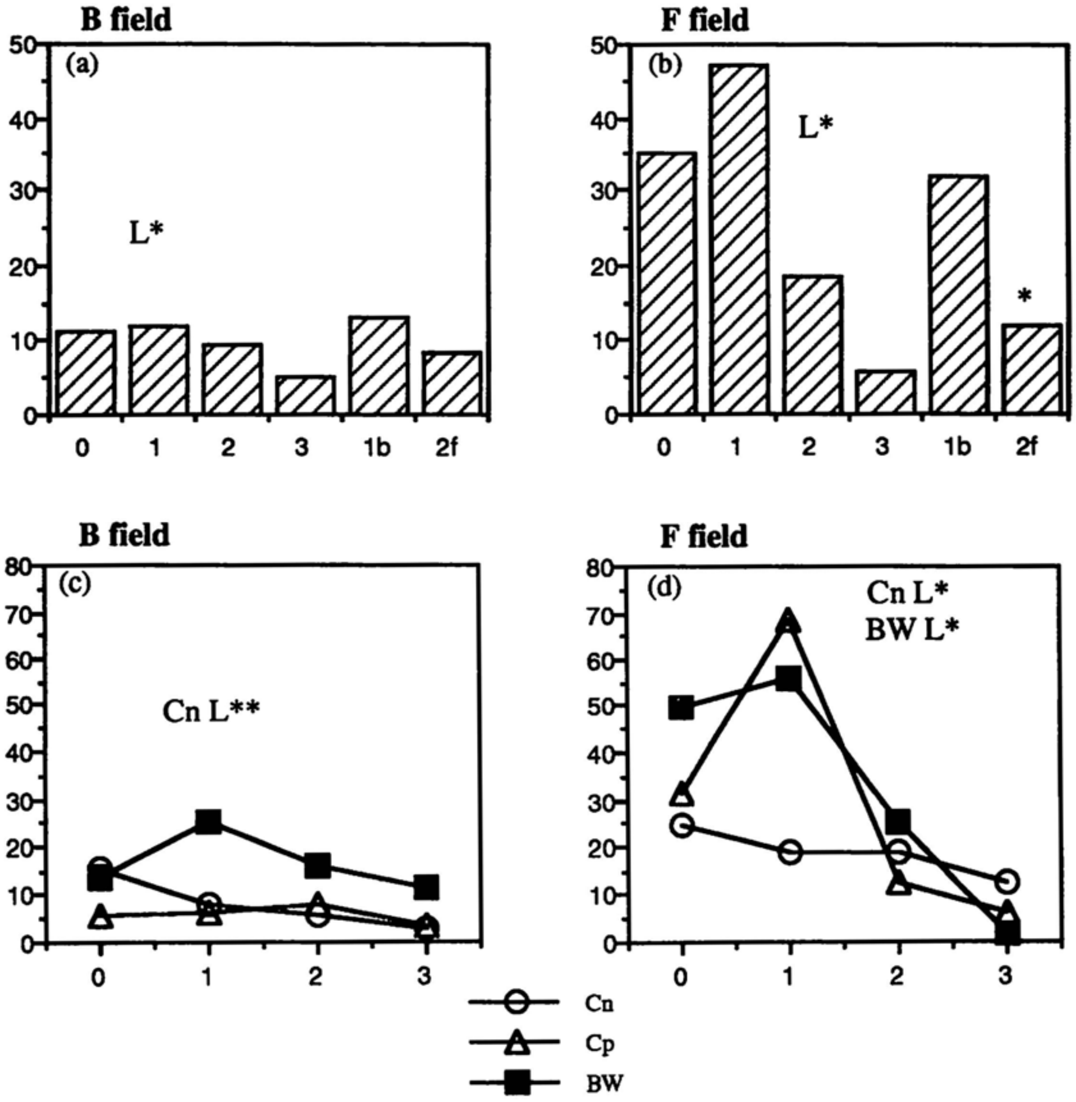


Figure F4. Percent red thread on April 28, 1994. Statistics conducted on arcsinsqrt transformed data.

B field (Split-plot)

MP (2,4): F=7.26, p=0.047
Sp (3,36): F=2.98, p=0.044
MP*Sp (6,36): F=1.29, p=0.285
cv MP = 43.6%
cv Sp, MP*Sp = 41.1%

F field (RCB)

Sp (3,12): F=7.21, p=0.005
cv Sp = 34.5%

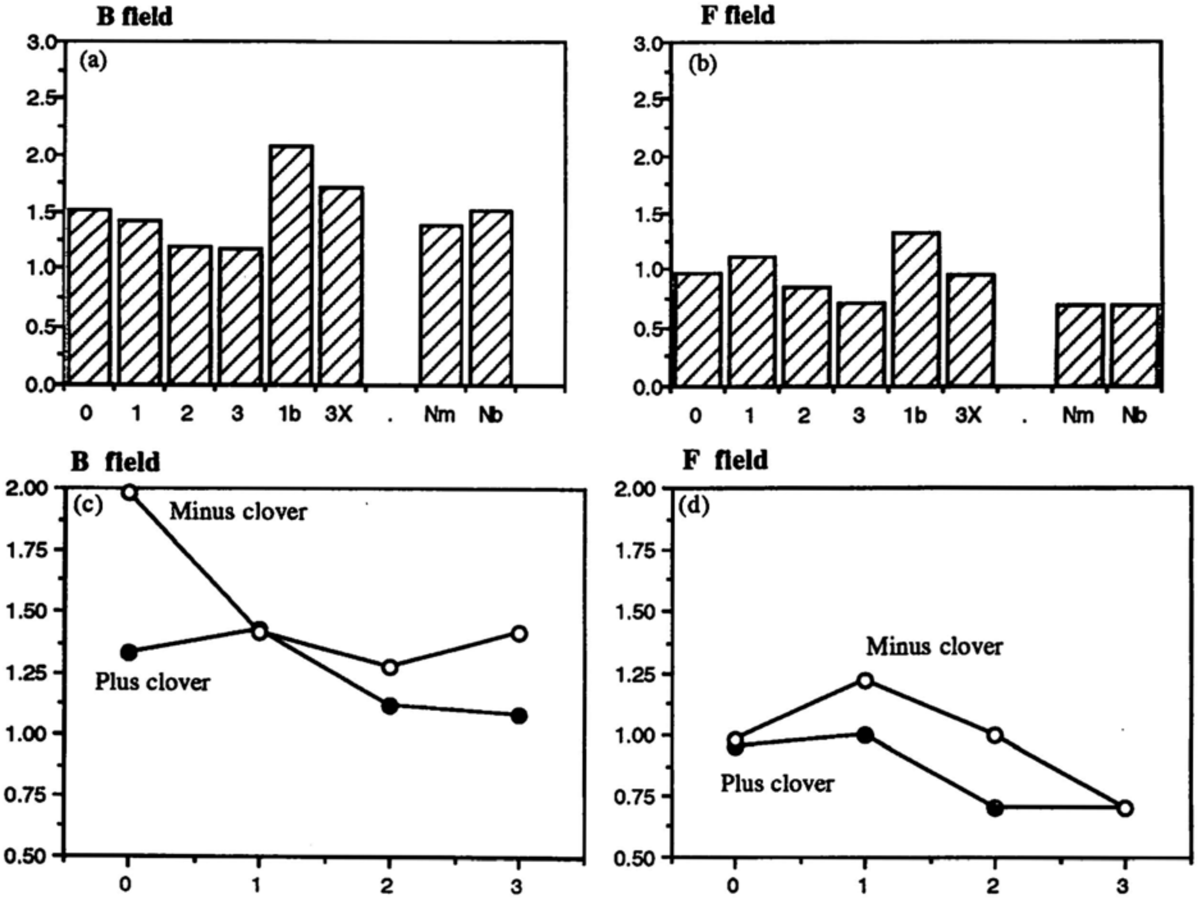


Figure F5. Rating (1-5) of anthracnose on July 11-14, 1994 on the B and F field for (a,b) OF subplots and NPK-Ecomix, average for all main plots and (c,d) OF subplots, average for plus and minus clover. Data were log transformed for analysis.

B field (Split-split-plot)

MP F (2,4): 0.19, p=0.834
Sp F (3,18): 0.84, p=0.487
MP*Sp F (6,18): 0.34, p=0.907
Clover F (1, 32): 1.68, p=0.204
MP*Clover F (2,32): 0.19, p=0.829
MP*Sp*Clover F (6,36): 0.74, p=0.621
cv MP = 20.1%
cv Sp, MP*Sp = 15.9%
cv Clover, MP*Clover, MP*Sp*Clover = 13.5%

F field (Split-plot)

Organofertilizer (3,6): 1.37, p=0.338
Clover (1,15): 0.14, p=0.711
cv Organofertilizer = 16.7%
cv Clover = 20.4%

Averages For Main Plots:
Cn = 1.01
Cp = 0.79
BW = 0.91

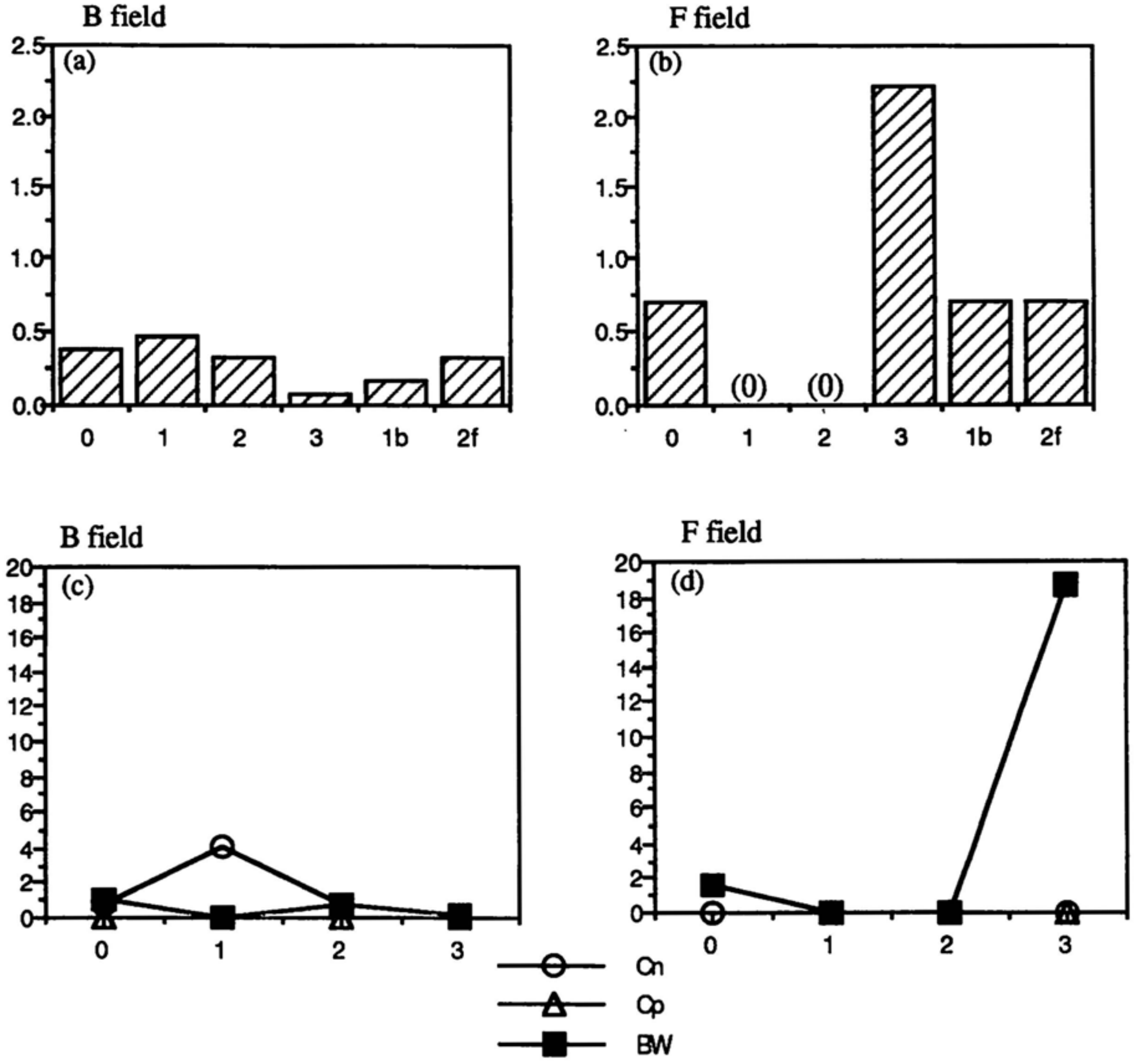


Figure F6. Percent pink snow mold on April 28, 1994. Statistics conducted on arcsinsqrt transformed data.

B field (Split-plot)	**F field (RCB)**
MP (2,4): F=0.79, p=0.512 Sp (3,36): F=0.70, p=0.559 MP*Sp (6,36): F=1.53, p=0.197 cv MP = 435% cv Sp, MP*Sp = 156%	Sp (3,12): F=1.16, p=0.364 cv Sp = 823%

Table F1. Presence and absence of red thread in 1.5 m x 1.5 m plots on November 17 and December 21, 1993, and sizes and numbers of patches on December 21.

Subplot	**Nov.17**	**Dec.21**	**Nov.17**	**Dec.21**	**Avg. No. Patches**	**Avg. No. Patches**	**Average Size**	**Average Size**
	B Field #/9	B Field #/9	F Field #/3	F Field #/3	B Field #/Quad.	F Field #/Quad.	B Field cm^2	F Field cm^2
OF 0a	4	7	1	3	3.3	2.9	383.3	57.0
OF 0b	1	5	1	3	3.3	2.0	67.1	336.2
OF 1m	2	8	1	3	4.3	2.4	146.5	404.1
OF 1b	4	7	2	1	1.3	2.3	59.5	33.2
OF 2	3	5	0	1	1.6	1.4	51.2	1.3
OF 2f	2	0	3	0	0.0	0.0	0.0	0.0
OF 3	2	2	1	2	1.6	1.2	26.6	20.9
OF 3a	3	6	1	1	1.0	2.1	74.4	70.4
	#/3	#/3	#/3	#/3				
NPK-bag	0		0	0	0.7	0.0	19.4	0.0
NPK-mulch	0		0	0	1.7	0.0	19.1	0.0

Table F2. Presence and absence of red thread in 1.5 m x1.5 m plots in November of 1994 (Blocks 1 and 4 only).

	Block 1			Block 4		
Subplot	Cn	Cp	BW	Cn	Cp	BW
OF 0a	++++	+	+++++	0	0	++
OF 0b	+	0	+++++	0	+	0
OF 1m	++	++	0	0	+	+
OF 1b	+	++	+	0	0	0
OF 2	+++	+	0	0	0	0
OF 2f	0	0	0	0	+	+
OF 3a	0	0	0	0	+	+
OF 3*	0	0	0	0	++	0
NPK-bag	+++			+		
NPK-mulch	+++++			0		
NPK-Ktb	0					

Key.

0: absent
+: present, but difficult to see
++: present, but very little
+++: present, low amount
++++: present, moderate amount
+++++: present, a lot

Table F3. Scoring of leaf spot on November 17, 1993. A negative sign indicates that leaf spot was revealed only by close inspection; 1 indicates it was present but without affecting overall quality significantly, and a 2 indicates that the plot stood out because of intensity of leaf spot. The three values cited for each of the B field cells correspond respectively to values for Block 1, 2, and 3.

	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3J	OF3A	NPKe	NPKk
B Field	- - -	- - -	- - -		- - -	- - -	- - -	- - -		
Cn	- - -	- - -	- - -	2 2 -	- - -	- - -	- - -	- - -	- - -	2 2 2
Cp	- - -	- - -	- - -	2 2 2	- - -	- - -	- - -	- - -		
BW	- - -	- - -	- - -	2 2 -	- - -	- - -	- - -	- - -		
F Field										
Cn	1	-	1	-	1	1	-	-	-	
Cp	1	-	-	1	-	1	-	-		
BW	-	-	-	-	-	-	-	-		

Table F4. Average percent occurence of disease symptoms on clover in 1993 and 1994.

Year, treatments	Blotches	Spots	Necrotic
<u>Aug 9, 1993</u>			
Blocks 1-3, all MP and subplots	9.5	4.7	1.6
Blocks 1-3 NPK-Eco, ecobag and Ktb	3.1	3.8	0.5
Block 4 all MP and subplots[1]	6.3	6.3	0
<u>July 14, 1994</u>			
Blocks 1-3, all MP and subplots	3.0	3.7	1.1
Blocks 1-3 NPK-Eco, ecobag and Ktb	4.9	2.8	12.5
Block 4 all MP and subplots	7.9	10.3	1.4

[1] Clover was present in only 3 of the 24 subplots, and there was no clover in the NPK plots.

G. Leaf nutrients

Nutrient concentrations in leaves were examined in order to identify possible nutrient limitations or excesses by comparing observed values to published sufficiency values (Table G1). Nutrient concentrations of grass tissue also acted as an indicator of differences in the nutrient supplying capacity of the main plot and subplot treatments.

Methods

Whole leaf samples (verdure and clippings) from the biomass sampling on Aug. 19, 1992, July 13, 1993, and Aug 11, 1994 were analyzed.

Nutrient sufficiency values usually refer to clippings. We compared values for macronutrients in clippings only with those in whole leaves for a subset of the 1993 samples (footnote in Table G1). Only the N and Mg values differed substantially with the whole leaf values. To assess possible N or Mg deficiency or excess based on the %N or %Mg values of our samples, we multiplied the reference values by 0.766 and 0.843 respectively (Table G1).

Selected samples were analyzed for macro (N,K,P,Ca,Mg,S) and micronutrients (Fe,Mn, B,Cu,Zn) and Na and Al as indicated in the Tables. Analyses were conducted by Acutest Laboratories in Nepean Ontario.

Results

Effects of main plot treatments and different levels of organofertilizer

Samples of vegetation from main plots in the absence of organofertilizer in mid-summer of 1992, 1993, and 1994 (Table G2), illustrate the following points:

- In 1992, N was higher in BW treatments on the B field than in Cn and Cp treatments, and there was higher N in Cn treatment on the F field than in Cp and BW treatments. This result is consistent with the ranking of greenness (Section III.1B) and verdure data (Section III.1A).

- On B field, Cp main plots had higher P than the other main plot treatments in all three years, and overall the P levels were maintained at higher levels over the three years.

- There was significantly higher K in the Cp treatment than in other treatments in 1992 and 1993 on the B field. In 1994 there was no difference. Potassium levels declined over the three years on both the B and F fields.

- Compared to reported minimum sufficiency levels:

  -N in the F field plots in 1993 were below minima on all main plots.
  -S in the F field plots in 1993 were below the sufficiency range.
  -Mg values on the F field were close to or below one of the reported minimum values in all years.

Low S on the F field is peculiar, and could have been a factor reducing protein synthesis (Shuman, 1994), and hence overall N content. It appears to been relieved in 1994 (Table G4).

- Compared to reported upper limits:

  -some P values were at or close to the limit (0.55%).
  -Fe and Mn exceeded upper limits, but not by large factors.

- Aluminum levels on the B field were elevated in the BW and NPK main plots. On the F field they were highest in NPK plot. The original data shows exceptionally high values on some individual plots, not on others.

The effects of organofertilizer and main plots treatments on macronutrient levels in 1993 and 1994 are illustrated in Fig. G1 and Table G3:

- Nitrogen: there is a significant linear (or quadratic saturation type) response of %N to organofertilizer only on the F field in 1993, which is what would be predicted based on levels in the OF0 samples.

- Phosphorus: several of the curves show negative linear trends or quadratic responses. Only 1993 F field data show a fairly strong positive response at the lower levels of organofertilizer, and the lowest %P at the OF0 level.

- Potassium: overall trends are for a positive response to K (i.e. organofertilizer increased K).

- Magnesium: strong negative responses to increasing organofertilizer, possibly related to increased K uptake, as K tends to be antagonistic to Ca and Mg; also the organofertilizer was high in Ca, low in Mg.

- Calcium: the effect of organofertilizer appears quite variable, although there appears to be a slight positive response on both fields in 1994.

Effects of bag mowing and withdrawal of organofertilizer in 1994

(1) *Bag mowing/mulch mowing (Table G4).*

- Bag mowing had its most significant effect on %N, reducing it by 0.61 units on average in minus clover samples in 1994 and by 0.35 units in plus clover samples. There is a suggestion of some reduction in K and very small reduction in P in bag mowed plots compared to mulch mowed plots.

- Trace elements do not show differences except for Fe and Al which are higher in the mulch-mowed compared to bag mowed treatments.

- Bag mowing of the OF1 plots reduced N on the B field, and N, P, and Mg on the F field below the OF0 values.

(2) *Cessation of use of organofertilizer on OF3 plots in 1994 (Table G5).*

- There were numerical and some significant reductions in N, P,K and Ca in the OF3X compared to the OF3 plots.

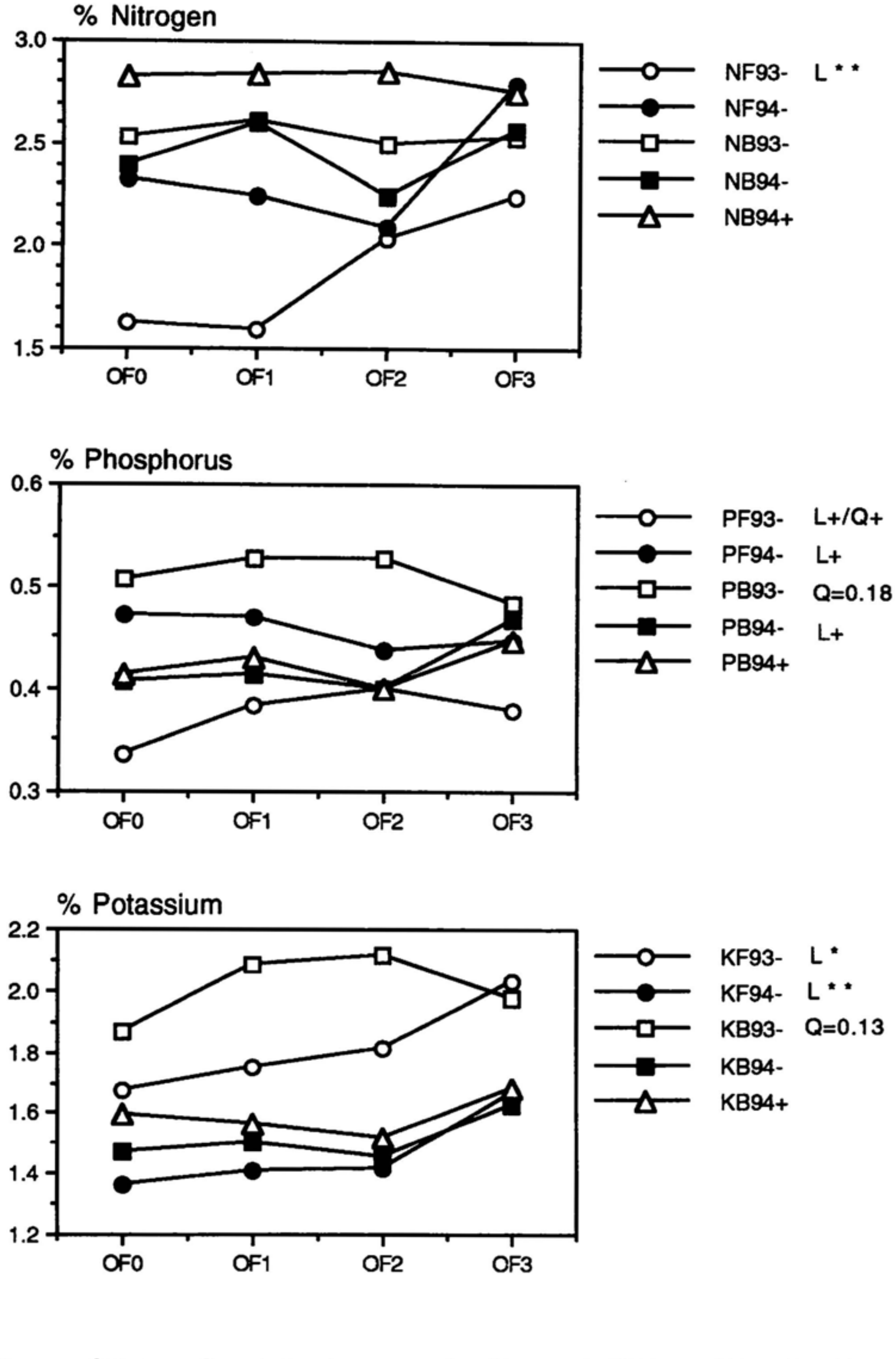


Figure G1. Leaf nutrient concentrations at different levels of organofertilizer. Values are averages for organofertilzer plots in Cn, Cp, and BW main plots. See Table G3 for main plot averages. In legend, the first letter refers to the nutrient (N,P,K, Mg, Ca), the second letter to the field (B or F), the number to the year (93 or 94), and the +/- to samples from grass only patches (-) or grass + clover patches (+).

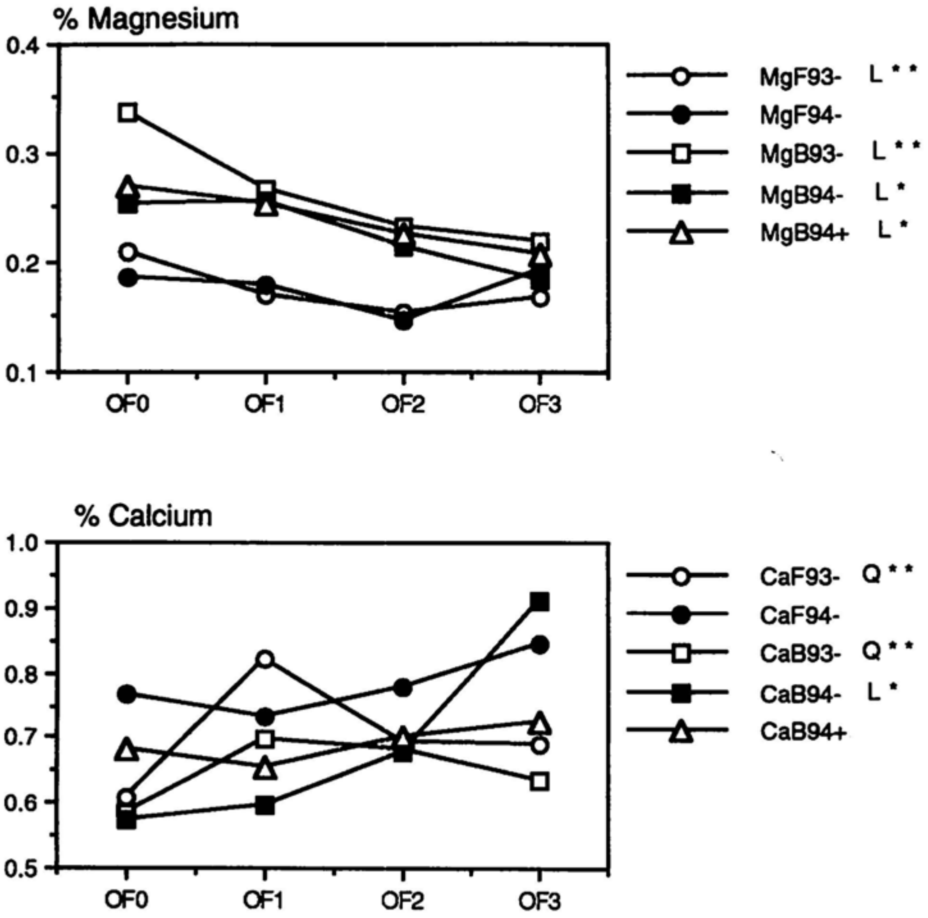


Figure G1. Concluded.

Table G1. General sufficiency levels for nutrient concentration in turfgrass clippings.

Element	OMAF, 1992	Jones, 1980
N %	2.5 - 6	2.75 - 3.5
N % (for whole leaves)[1]	1.9 - 4.6	2.1 - 2.7
P %	0.15 - 0.55	0.3 - 0.55
K %	0.9 - 4.0	1.0 - 2.5
Ca %	0.2 - 4.5	0.5 - 1.25
Mg %	0.15 - 1.0	0.2 - 0.6
Mg % (for whole leaves)	0.13 - 0.84	0.17 - 0.51
S %		0.2 - 4.5
Fe mg kg^{-1} (ppm)		35 - 100
Mn mg kg^{-1} (ppm)	20 - 140	25 - 150
Zn mg kg^{-1} (ppm)	10 - 100	20 - 55
Cu mg kg^{-1} (ppm)	5 - 30	5 - 20
B mg kg^{-1} (ppm)	3 - 30	10 - 60
Mo mg kg^{-1} (ppm)[2]		not known

[1] Whole leaf value is reported value multiplied by 0.766 (N) or 0.843 (Mg); see Table below.

[2] Shuman (1994) gives critical level of Mo as 0.1-1 ppm

For macronutrients, values for clippings and whole leaves were similar except for N and Mg (1993 data, n=24):

Nutrient	R^2 for Regression of Nutrient in Clippings to Nutrient in Whole Leaves	Average Ratio of Nutrient in Clippings to Nutrient in Whole Leaves
N	0.686 (p=0.0001)	0.766
P	0.853	0.953
K	0.540	0.999
Mg	0.843	0.843
Ca	0.061	0.979

Table G2. Leaf nutrient concentrations on August 19, 1992, July 13, 1993, and Aug. 11, 1994, on main plots outside of organofertilizer plots (92, 93) or on OF0 plots (94).

Nutrient	Year	B/F	Clo[1]	Cn	Cp	BW	NPK	F-value[2]	p-value
N (%)	1992	B		3.06 a	3.36 a	4.09 b		(2,4): 12.3	0.019
		F		2.89	2.25	2.22			
	1993	B		2.62	2.60	2.40	2.38	(3,6): 1.59	0.287
		F		1.67	1.86	1.36	1.70		
	1994	B		2.44	2.47	2.26			
		F		2.41	2.15	2.40	2.03		
		B	cl	2.99	2.67	2.80	2.87		
		F	cl	2.71	2.15	2.75			
P (%)	1992	B		0.41 a	0.54 b	0.36 a		(2,4): 49.2	0.001
		F		0.46	0.41	0.44			
	1993	B		0.47	0.56	0.50	0.46	(3,6): 2.14	0.196
		F		0.37	0.35	0.29	0.39		
	1994	B		0.37	0.44	0.41			
		F		0.46	0.50	0.46	0.42		
		B	cl	0.41	0.44	0.39	0.42		
		F	cl	0.46	0.50	0.48			
K (%)	1992	B		2.05 a	2.84 b	1.78 a		(2,4): 15.6	0.013
		F		2.54	2.20	2.25			
	1993	B		1.72 a	2.37 c	1.50 a	2.05 b	(3,6): 24.0	0.001
		F		1.66	1.86	1.48	2.10		
	1994	B		1.54	1.55	1.32			
		F		1.38	1.37	1.34	1.47		
		B	cl	1.58	1.72	1.48	1.63		
		F	cl	1.67	1.37	1.84			
Mg (%)	1992	B		0.28 a	0.18 a	0.41 b		(2,4): 13.7	0.016
		F		0.14	0.15	0.13			
	1993	B		0.32 a	0.27 a	0.42 b	0.26 a	(3,6): 11.2	0.007
		F		0.21	0.23	0.19	0.20		
	1994	B		0.28	0.23	0.25			
		F		0.22	0.18	0.16	0.14		
		B	cl	0.32	0.23	0.26	0.23		
		F	cl	0.23	0.18	0.18			
Ca (%)	1992	B		0.60 a	0.48 a	0.73 b		(2,4): 15.3	0.013
		F		0.68	0.57	0.70			
	1993	B		0.53 a	0.57 ab	0.66 b	0.49 a	(3,6): 4.40	0.058
		F		0.67	0.57	0.58	0.59		
	1994	B		0.47	0.59	0.66			
		F		0.73	0.82	0.75	0.73		
		B	cl	0.68	0.70	0.67	0.69		
		F	cl	0.85	0.82	0.94			

Table G2. Continued...

Nutrient	Year	B/F	Clo	Cn	Cp	BW	NPK	F-value	p-value
S (%)	1993	B		0.40	0.42	0.55	0.35	(3,6): 2.65	0.143
		F		0.17	0.14	0.15	0.19		
	1994	B		0.26					
		F		0.27					
		B	cl	0.24					
		F	cl	0.25					
Fe (ppm)	1993	B		138.7	125.0	158.0	199.3	(3,6): 0.34	0.794
		F		161.0	124.0	179.0	161.0		
	1994	B		99.0					
		F		123.0					
		B	cl	102.0					
		F	cl	96.0					
Mn (ppm)	1993	B		200.3	163.0	211.7	196.0	(3,6): 1.89	0.231
		F		245.0	184.0	237.0	225.0		
	1994	B		110.0					
		F		120.0					
		B	cl	139.0					
		F	cl	90.0					
B (ppm)	1993	B		7.00	8.67	8.00	7.67	(3,6): 0.52	0.684
		F		9.00	10.0	8.00	9.00		
	1994	B		5.00					
		F		7.00					
		B	cl	8.00					
		F	cl	9.00					
Cu (ppm)	1993	B		8.00	8.00	6.00	6.67	(3,6): 1.44	0.321
		F		5.00	5.00	4.00	5.00		
	1994	B		5.00					
		F		3.00					
		B	cl	7.00					
		F	cl	5.00					
Zn (ppm)	1993	B		35.3	37.3	35.3	30.3	(3,6): 1.37	0.340
		F		26.0	22.0	22.0	25.0		
	1994	B		40.0					
		F		34.0					
		B	cl	40.0					
		F	cl	36.0					

Table G2. Concluded.

Nutrient	Year	B/F	Clo	Cn	Cp	BW	NPK	F-value	p-value
Mo (ppm)	1993	B		7.33	6.67	6.33	4.67	(3,6): 1.27	0.365
		F		5.00	5.00	3.00	2.00		
	1994	B		6.00					
		F		4.00					
		B	cl	3.00					
		F	cl	4.00					
Na (%)	1993	B		0.09 a	0.09 a	0.13 b	0.07 a	(3,6): 5.95	0.031
		F		0.04	0.09	0.05	0.06		
	1994	B		0.08					
		F		0.05					
		B	cl	0.08					
		F	cl	0.07					
Al (ppm)	1993	B		54.0	60.7	182.0	167.3	(3,6): 1.02	0.446
		F		98.0	92.0	70.0	116.0		
	1994	B		50.0					
		F		90.0					
		B	cl	44.0					
		F	cl	48.0					

1 Under Clo, "cl" denotes samples including clover. Other samples did not include clover.

2 Statistics are given for the B field in 1992 and 1993 when each Block was analyzed.

Table G3. Leaf nutrient concentrations in different main plots; values are averages for OF0, OF1, OF2, and OF3 subplots. +/- indicate samples with and without clover.

% Nitrogen

Date/Field/Clover	*Cn*	*Cp*	*BW*
93F-	1.86	1.99	1.78
94F-	2.30	2.44	2.35
93B-	2.64	2.64	2.37
94B-	2.62	2.22	2.42
94B+	2.89	2.68	2.88

% Phosphorus

Date/Field/Clover	*Cn*	*Cp*	*BW*
93F-	0.375	0.410	0.340
94F-	0.433	0.488	0.450
93B-	0.508	0.535	0.492
94B-	0.393	0.453	0.430
94B+	0.418	0.440	0.410

% Potassium

Date/Field/Clover	*Cn*	*Cp*	*BW*
93F-	1.77	1.88	1.79
94F-	1.39	1.52	1.49
93B-	1.97	2.29	1.76
94B-	1.60	1.55	1.40
94B+	1.59	1.69	1.49

% Magnesium

Date/Field/Clover	*Cn*	*Cp*	*BW*
93F-	0.168	0.190	0.168
94F-	0.193	0.173	0.165
93B-	0.269	0.226	0.300
94B-	0.260	0.190	0.213
94B+	0.268	0.218	0.232

% Calcium

Date/Field/Clover	*Cn*	*Cp*	*BW*
93F-	0.742	0.640	0.725
94F-	0.830	0.758	0.758
93B-	0.630	0.630	0.692
94B-	0.705	0.667	0.713
94B+	0.725	0.685	0.668

Table G4. Nutrient concentrations in turf from bag mowed and mulch mowed plots, not including (-) or including (+) clover; Aug. 11, 1994.

B Field

	N		P		K		Mg		Ca	
Treatment	-	+	-	+	-	+	-	+	-	+
Cn 1m	2.76	2.93	0.42	0.41	1.66	1.55	0.29	0.30	0.55	0.62
Cn 1b	1.97	2.54	0.37	0.39	1.24	1.27	0.30	0.33	0.65	0.71
Cn 0	2.44	2.99	0.37	0.41	1.54	1.58	0.28	0.32	0.47	0.68
Cp 1m		2.87		0.46		1.72		0.22		0.66
Cp 1b		2.46		0.46		1.70		0.19		0.68
Cp 0	2.47	2.67	0.44	0.44	1.55	1.72	0.23	0.23	0.59	0.70
BW 1m	2.46	2.72	0.41	0.42	1.34	1.43	0.22	0.24	0.64	0.69
BW 1b	2.17	2.46	0.42	0.46	1.33	1.33	0.22	0.27	0.61	0.82
BW 0	2.26	2.80	0.41	0.39	1.32	1.48	0.25	0.26	0.66	0.67
N 1m	2.57	2.87	0.39	0.42	1.46	1.63	0.21	0.23	0.63	0.69
N 1b	2.02	2.36	0.37	0.42	1.45	1.46	0.21	0.24	0.63	0.85
Mulch, all MP	2.61	2.84	0.42	0.43	1.50	1.57	0.26	0.25	0.60	0.66
Bagged, all MP	2.07	2.49	0.40	0.44	1.28	1.43	0.26	0.26	0.63	0.74
OF0	2.39	2.82	0.41	0.41	1.47	1.59	0.25	0.27	0.57	0.68
Clover, all MP	2.34	2.66	0.40	0.43	1.39	1.50	0.26	0.26	0.61	0.70
Signif[1] B/M	0.056		0.735		0.333		0.899		0.298	
Signif -/+cl	0.048		0.168		0.965		0.039		0.123	
Signif of Interaction B/M * cl	0.281		0.168		0.828		0.155		0.426	
Signif 1b/0	0.052		0.551		0.424		0.469		0.394	

F Field

	N		P		K		Mg		Ca	
Treatment	-	+	-	+	-	+	-	+	-	+
Cn 1m	2.18		0.42		1.25		0.25		0.82	
Cn 1b	2.13	2.54	0.42	0.39	1.22	1.27	0.20	0.33	0.77	0.71
Cn 0	2.41		0.46		1.38		0.22		0.73	
Cp 1m	2.36		0.53		1.56		0.15		0.67	
Cp 1b	1.79		0.37		1.28		0.16		0.74	
Cp 0	2.15		0.50		1.37		0.18		0.82	
BW 1m	2.19		0.46		1.41		0.14		0.71	
BW 1b	1.84		0.39		1.37		0.13		0.78	
BW 0	2.40		0.46		1.34		0.16		0.75	
N 1m	2.03		0.42		1.47		0.14		0.73	
N 1b	1.76		0.39		1.38		0.14		0.83	
Mulch, all MP	2.19		0.45		1.42		0.17		0.73	
Bagged, all MP	1.88		0.39		1.31		0.16		0.78	
OF0	2.32		0.47		1.36		0.19		0.77	
Signif B/M	0.063		0.158		0.155		0.412		0.248	
Signif B/O	0.041		0.094		0.317		0.020		0.938	

Table G4. Concluded.

	S		Na		Fe		Mn		B	
Treatment	-	+	-	+	-	+	-	+	-	+
B: Cn 1m	0.26	0.21	0.06	0.10	203	130	70	124	5	6
B: Cn 1b	0.29	0.22	0.10	0.09	73	80	68	140	5	7
B: Cn 0	0.26	0.24	0.08	0.08	99	102	110	139	5	8
F: Cn 1m	0.23		0.12		430		86		7	
F: Cn 1b	0..25	0.22	0.03	0.09	114	80	95	140	7	7
F: Cn 0	0.27	0.25	0.05	0.07	123	96	120	90	7	9

	Cu		Zn		Al		Mo	
Treatment	-	+	-	+	-	+	-	+
B: Cn 1m	4	5	28	36	240	94	6	3
B: Cn 1b	4	4	25	32	40	30	5	3
B: Cn 0	5	7	40	40	50	44	6	3
F: Cn 1m	4		35		608		2	
F: Cn 1b	4	4	35	32	99	30	3	3
F: Cn 0	3	5	34	36	90	48	4	4

[1] p-values for bag versus mulch mowing effect (B/M), presence or absence of clover (-/+ cl), interaction of mowing method with clover effect (B/M*cl), and for comparison of bag mowed plots (OF1b) with OF0 plots.

Table G5. Nutrient concentrations in turf from OF3 plots receiving (3) and not receiving (3X) organofertilizer in 1994; (-) and (+) refer to absence or presence of clover.

B field

	N		P		K		Mg		Ca	
Treatment	-	+	-	+	-	+	-	+	-	+
Cn 3	3.23	3.06	0.41	0.48	1.80	1.72	0.25	0.22	1.09	0.90
Cn 3X	2.39	2.67	0.32	0.42	1.38	1.42	0.25	0.25	0.67	0.79
Cn 0	2.44	2.99	0.37	0.41	1.54	1.58	0.28	0.32	0.47	0.68
Cp 3	2.02	2.75	0.51	0.44	1.62	1.71	0.14	0.21	0.76	0.66
Cp 3X	1.89	2.63	0.42	0.42	1.38	1.60	0.15	0.21	0.71	0.73
Cp 0	2.47	2.67	0.44	0.44	1.55	1.72	0.23	0.23	0.59	0.70
BW 3	2.46	2.47	0.48	0.42	1.47	1.62	0.16	0.19	0.88	0.62
BW 3X	2.60	2.32	0.41	0.42	1.34	1.47	0.22	0.22	0.65	0.70
BW 0	2.26	2.80	0.41	0.39	1.32	1.48	0.25	0.26	0.66	0.67
3, all MP	2.57	2.76	0.47	0.45	1.63	1.68	0.18	0.21	0.91	0.73
3X. all MP	2.29	2.54	0.38	0.42	1.37	1.50	0.21	0.23	0.68	0.74
0, all MP	2.39	2.82	0.41	0.41	1.47	1.59	0.25	0.27	0.57	0.68
Clover, all MP	2.43	2.65	0.42	0.43	1.49	1.59	0.19	0.22	0.79	0.73
Signif[1] 3/3X	0.31		0.04		0.08		0.21		0.31	
Signif -/+cl	0.34		0.78		0.10		0.29		0.09	
Interaction B/M* cl	0.89		0.36		0.42		0.93		0.01	
Signif 3x/0	0.11		0.55		0.19		0.01		0.19	

F field (Minus Clover Only)

Treatment	N	P	K	Mg	Ca
Cn 3	2.50	0.44	1.60	0.15	0.97
Cn 3X	2.09	0.39	1.37	0.16	0.84
Cn 0	2.41	0.46	1.38	0.22	0.73
Cp 3	3.05	0.46	1.73	0.22	0.83
Cp 3X	3.05	0.46	1.73	0.22	0.83
Cp 0	2.15	0.50	1.37	0.18	0.82
BW 3	2.83	0.44	1.66	0.21	0.74
BW 3X	2.83	0.44	1.66	0.21	0.74
BW 0	2.40	0.46	1.34	0.16	0.75
3, all MP	2.79	0.45	1.66	0.19	0.84
3X. all MP	2.66	0.43	1.59	0.20	0.80
0, all MP	2.42	0.48	1.50	0.19	0.82
Signif 3/3X	0.42	0.42	0.42	0.42	0.42
Signif 3X/0	0.44	0.00	0.59	0.83	0.81

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[1] See footnotes in Table G4.

H. Nutrient removal by bag mowing

Mowing is a fundamental cultural practice which has implications on soil fertility and turf health. We anticipated that bag mowing, by removing nutrients would have a negative impact on turf compared to the equivalent plots that were mulch mowed (clippings cycled). It was expected that the effects of bag mowing would be reduced somewhat at higher levels of fertilization.

Methods

In 1994, clippings were taken from Cp1 and Cp1b plots (Compost main plot - mulch mowed and bag mowed receiving 1 lb organofertilizer-N per season) through the growing season. Clippings were harvested at 7.5 cm height in one 25 x 25 cm quadrat placed in each of the four Cp1 and four Cp1b plots just before maintenance personnel did the regular mowing. The position of the quadrat was noted and the quadrat was rotated around the plot in successive samplings. Harvested material was dried in a forced air draft oven.

At the end of the season, all clippings were combined for the B and F field bag and mulch mow treatments. Clover was separated from grass and each component weighed to give total seasonal production. These eight batches of plant material were analyzed for macro and micronutrients, plus Al and Na.

Results

Seasonal production of dry matter is shown in Figure H1.

- The mulch mowed plots on the B field yielded more clippings than those on the F field except for about a 40 day period in June-July, when yields were similar. The F field lagged behind the B field by about one month early in the season. On both fields, production declined from July though to the end of September.

This is a typical pattern for temperate regions, however, clipping yield generally increases to near-spring levels with the onset of cooler weather and rain in the latter part of summer and early fall (Hull, 1992). In this case there was a smaller amplitude increase towards the end of August, and then clipping production continued to decline. September was unusually dry (Section VII-Appendix 1). In October and November, production picked up on the B field, but not on the F field, which appeared to go into early dormancy.

The pattern of production in the bag mow treatments was very similar to that for the mulch mowed treatments on the B field, but with lower amplitude (Fig. H1). On the F field, however, production in bag mowed plots declined after an initial peak in early June, in contrast to the sustained high production in the mulch mowed plots through the rest of June and early July. Similarly in late August, the bag mowed plots did not exhibit an increase in production as was observed for the mulch mowed plots. We attribute these differences to greater drought stress on the bag mowed plots.

- Total seasonal clipping production was 701 and 414 g m^{-2} on the B field and 367 and 162 g m^{-2} on the F field, mulch and bag mowed plots respectively (Table H1).

- The variation in seasonal clipping yield is much greater than variation in verdure (corresponding verdure values for July were 365/382; 295/311 g m^{-2} for B field, bag/mulch; F field, bag/mulch respectively).

Given that the nutrient concentration in clippings is equal to or greater than that in verdure, this suggests that the quantity of nutrients cycling or removed in clippings could be approximately one half (as in F field bag mowed plots) to two times that in verdure (as in B field mulch mowed plots).

- On the B field, clover contributed 11% and 28% of total dry matter production in mulch and bag mowed plots respectively, while on the F field the corresponding figures were 14% and 7% (Table H1).

- The F field bag mowed + clover sample had low concentrations of N, P, K and Mo compared to grass and to clover on the mulch mowed plots (Table H2). Mo was below the detectable level of 1 ppm; the critical value for clover is variously quoted as 0.5 to 1 ppm (Shuman, 1994).

Legumes generally compete poorly with grasses for K when it is present in low amounts (Floate, et.al., 1981). Molybdenum is required for the N_2-fixing enzyme, thus Mo limitation might account for the very low %N in the clover.

There were large variations in the total amounts of nutrients cycled or removed via clippings.

- In the case of N, the highest of the values (29.9, 17.7 g m^{-2} for B field, mulch and bag mowed, and 11.7 and 4.1 g m^{-2} for F field, mulch and bag mowed plots respectively) is equivalent to 6 lbs N per 1000 sq ft per annum (Table H3). Bag mowing removed 177 kg N, 20.5 kg P and 89 kg K per hectare from the B field, and 41 kg N, 7 kg P and 30 kg K from the F field.

How did main plot treatments influence bag mowing?

It was postulated that the effects of bag mowing would be less pronounced at higher levels of fertilization or soil fertility, than at lower levels. In addition to bag mowed/mulch mow plots in the Cn, Cp and BW main plots, plots were established and maintained in the NPK main plots (3 lbs N per annum), and in organofertilizer strips on the Cp main plots that had been fertilized with organofertilizer at 3 lbs N per annum since the beginning of the experiment. Verdure was measured on all plots with samples taken from plus and minus clover areas, on July 14, 1995.

- The interaction of main plot and mowing type was not significant (Fig. H2a). Plots of values of verdure in mulch and bag mowed plots show steepest declines for the NPK and BW main plots. The slopes for the Cp main plot at 1 lb and 3 lbs of N are very similar.

Thus there is no evidence that effects of bag mowing were reduced at the higher fertility levels, and there is some suggestion that they were more pronounced in the NPK main plot, and in the BW1 plots compared to Cn1, Cp1 and Cp3 plots.

Data presented in Figure H2b show a significant effect of bag mowing on the ratio of clippings (1 week) to verdure (F (1,10) Mowing Type = 17.8, p= 0.0018). Clippings (1 week) were equivalent to 17% of verdure on mulch mowed plots and 10% on bag mowed plots.

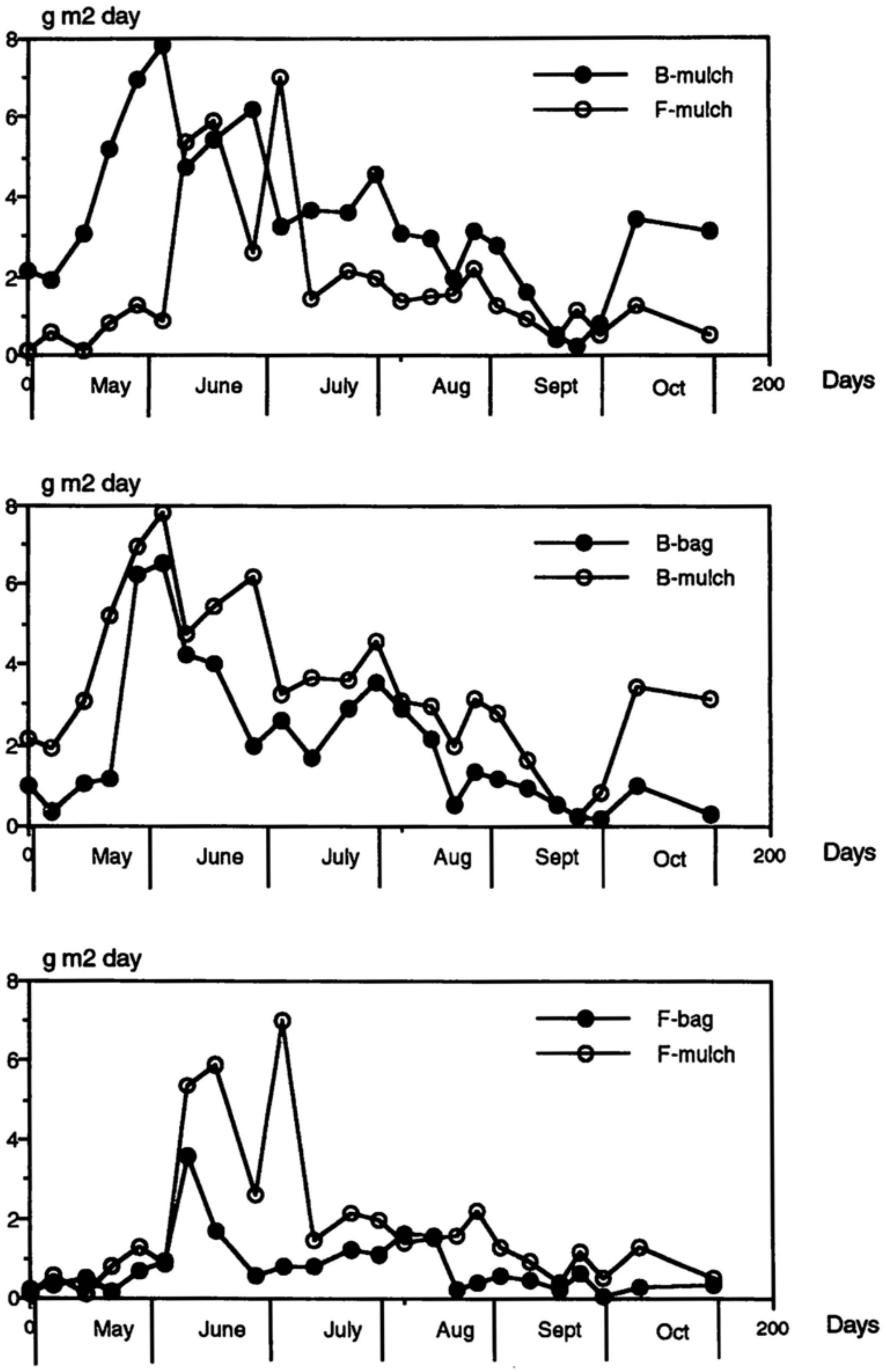
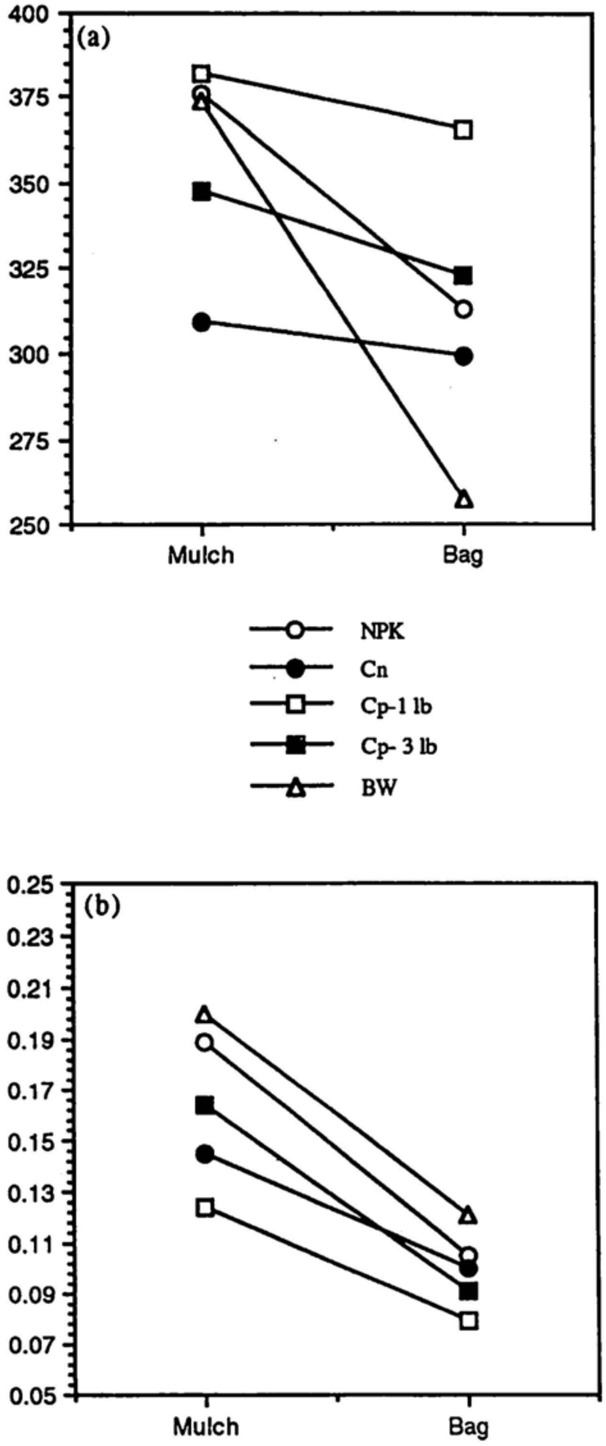


Figure H1. Seasonal production of dry matter, May - October, 1994. Top figure shows production difference between the two fields, middle figure shows production difference between bag and mulch mow plots on the B field, and bottom figure shows production difference between bag and mulch mow plots on the F field.



Verdure
(Split-split plot)

MP F (4,8): 1.82, p=0.2191
Mowing Type F (1,10): 5.63, p=0.0390
MP*Mowing Type F (4,10): 1.59, p=0.2508
cv MP = 14.3%
cv MT, MP*MT = 15.9%

Ratio, Clippings:Verdure
(Split-split plot)

MP F (4,8): 1.11, p=0.4165
Mowing Type F (1,10): 17.7, p=0.0018
MP*Mowing Type F (4,10): 0.09, p=0.9845
cv MP = 38.7%
cv MT, MP*MT = 35.6%

Figure H2. (a) Verdure (g m^{-2}) on bag and mulch mowed plots for each main plot. (b) Ratio of clippings to verdure on bag and mulch mowed plots for each main plot.

Table H1. Total seasonal clipping production on bag and mulch mow plots on the B and F fields in 1994. Verdure values for July 1994 are also included.

Field, plot	Component	$g\ m^{-2}\ yr$
B bag	Grass Clippings	298
	Clover	116
	Total	414
B mulch	Grass Clippings	624
	Clover	77.2
	Total	701
F bag	Grass Clippings	151
	Clover	11.3
	Total	162
F mulch	Grass Clippings	316
	Clover	51.4
	Total	367
Verdure: July 1994		$g\ m^{-2}$
B bag	Verdure	365
B mulch	Verdure	382
F bag	Verdure	295
F mulch	Verdure	311

Table H2. Nutrient concentrations of grass and clover from bag and mulch mowed plots.

Trt.	Grass/ Clover	N %	P %	K %	Mg %	Ca %	S %	Na %
B bag	grass	3.87	0.51	2.20	0.27	0.49	0.34	0.06
B mulch	grass	4.15	0.55	2.29	0.28	0.48	0.28	0.08
F bag	grass	2.57	0.46	1.96	0.24	0.60	0.35	0.06
F mulch	grass	2.96	0.59	2.07	0.22	0.58	0.28	0.01
B bag	clover	5.32	0.46	2.01	0.33	1.22	0.14	0.12
B mulch	clover	5.26	0.48	2.08	0.34	1.13	0.13	0.13
F bag	clover	1.74	0.17	0.78	0.19	0.71	0.18	0.07
F mulch	clover	4.54	0.46	2.11	0.25	1.30	0.12	0.10

Trt.	Grass/ Clover	Fe ppm	Mn ppm	B ppm	Cu ppm	Zn ppm	Al ppm	Mo ppm
B bag	grass	95.0	100.0	7.0	10.0	49.0	12.0	6.0
B mulch	grass	94.0	73.0	7.0	11.0	46.0	13.0	7.0
F bag	grass	90.0	104.0	13.0	8.0	48.0	28.0	3.0
F mulch	grass	81.0	85.0	8.0	7.0	49.0	11.0	4.0
B bag	clover	136.0	72.0	27.0	13.0	41.0	23.0	6.0
B mulch	clover	119.0	70.0	26.0	12.0	45.0	18.0	6.0
F bag	clover	123.0	64.0	29.0	10.0	37.0	25.0	0.0
F mulch	clover	105.0	58.0	25.0	11.0	38.0	11.0	3.0

Table H3. Total amount of nutrients cycled or removed via clippings.

Trt	Grass/ Clover	N $g\ m^{-2}$	P $g\ m^{-2}$	K $g\ m^{-2}$	Mg $g\ m^{-2}$	Ca $g\ m^{-2}$	S $g\ m^{-2}$	Na $g\ m^{-2}$
B bag	grass	11.53	1.52	6.56	0.80	1.46	1.01	0.18
B mulch	grass	25.88	3.43	14.28	1.75	2.99	1.75	0.50
F bag	grass	3.88	0.69	2.96	0.36	0.90	0.53	0.09
F mulch	grass	9.34	1.86	6.53	0.69	1.83	0.88	0.19
B bag	clover	6.16	0.53	2.33	0.38	1.41	0.16	0.14
B mulch	clover	4.06	0.37	1.61	0.26	0.87	0.10	0.10
F bag	clover	0.20	0.02	0.09	0.02	0.08	0.02	0.01
F mulch	clover	2.33	0.24	1.08	0.13	0.67	0.06	0.05
B bag	all	17.70	2.05	8.90	1.19	2.87	1.18	0.32
B mulch	all	29.90	3.80	15.90	2.01	3.87	1.85	0.60
F bag	all	4.10	0.71	3.00	0.38	0.99	0.55	0.10
F mulch	all	11.70	2.10	7.60	0.82	2.50	0.95	0.24

Trt	Grass/ Clover	Fe $mg\ m^{-2}$	Mn $mg\ m^{-2}$	B $mg\ m^{-2}$	Cu $mg\ m^{-2}$	Zn $mg\ m^{-2}$	Al $mg\ m^{-2}$	Mo $mg\ m^{-2}$
B bag	grass	28.31	29.80	2.09	2.98	14.60	3.58	1.79
B mulch	grass	58.63	45.53	4.37	6.86	28.69	8.11	4.37
F bag	grass	13.57	15.68	1.96	1.21	7.24	4.22	0.45
F mulch	grass	25.57	26.83	2.53	2.21	15.47	3.47	1.26
B bag	clover	15.75	8.34	3.13	1.51	4.75	2.66	0.69
B mulch	clover	9.19	5.40	2.01	0.93	3.47	1.39	0.46
F bag	clover	1.40	0.73	0.33	0.11	0.42	0.28	0.00
F mulch	clover	5.40	2.98	1.28	0.57	1.95	0.57	0.15
B bag	all	44.10	38.10	5.21	4.41	19.40	6.24	2.48
B mulch	all	67.80	50.90	6.37	7.79	32.20	9.50	4.83
F bag	all	15.00	16.40	2.29	1.32	7.70	4.51	0.45
F mulch	all	31.00	29.80	3.81	2.78	17.40	4.04	1.42

I. Physical, chemical, and biological properties of soil

The physical, chemical and biological properties of soil are determined by the parent material, climate, vegetation, management and the length of time these factors have been operational. Vegetation and management have a strong influence on these properties. Organic management is often characterized as one of "feeding the soil" rather than the "plants", the concept being that a healthy soil will support vigorous crops (Lampkin, 1990). Some of the features that organic agriculturalists have maintained are important for a healthy soil include good structure, high microbial activity, a properly balanced ion exchange complex (with 65-75% Ca, 10-15% Mg, 2-5% K, and 10-20% H), desirable microbes and metazoans (soil fauna), and desirable rhythms in the turnover of plant nutrients, hydrogen ions and various biologically active materials such as plant hormones and phytotoxins (Walters, 1979). In recent years, there have been efforts to develop indices of soil quality that take into account a wide variety of features (Table I1).

An often quoted principle of organic agriculturalists is to supply nutrients in "insoluble but available" form (Albrecht, 1975), the idea being that insoluble nutrients will not be subject to leaching or create problems due to excess, such as suppression of mycorrhizal infection of roots by high soluble P. Biological processes make the insoluble nutrients available, and "feeding the soil" with organic matter feeds the microorganisms and soil fauna which in turn can mobilize the nutrients from insoluble or poorly available form. Insoluble forms include organic matter which can hold most of the N and S, and about half the P in a soil, natural or added "rock powders" which can act as reservoirs of P, K and trace elements, and coarse limestone. Often, lack of an insoluble or slowly soluble source of potassium (e.g. some zeolites and some granites) is a limitation to applying this principle, and organic certification codes allow application of potassium as the highly soluble potassium sulfate or Langbenite (Sul-Po-Mag). Potash (KCl), although a natural product, is not allowed because of the toxicity of chloride.

In The Oaks experiments, the "insoluble but available" principle was tested or applied in various ways (experiments with organofertilizers; mulch mowing/bag mowing, Rock-P and humates were *tests* of the principle; the application of limestone on the B field, partly as coarse material, and partly as fine material was an *application* of the principle). A major, largely unanswered question is how this type of management affects the soil variables commonly measured in soil audits (organic matter, pH, lime requirement, P,K,Ca, Mg, sometimes CEC), and to what extent the criteria for adequacy of supply applied to conventional soil audits, apply to organic systems. For example, does the rating system normally applied to P and K apply if biological processes are operative that make P and K available from "unavailable" forms?

The measurements of physical, chemical and biological soil variables reported in this section were undertaken for several purposes:

> (1) to characterize the environment in which the experiments were conducted, so that readers can judge to what extent the results might be applicable to other environments,
>
> (2) to document effects of the different treatments on some parameters of soil quality (organic matter, bulk density, pH, soil biological activity),
>
> (3) to provide data that might explain anomalous results in other areas of the study, and,
>
> (4) to determine as possible, how predictive the soil tests are of turf nutritional status (Section III.1J).

Methods

Routine sampling and soil chemistry measurements

Soil samples were taken from fertility treatments, or a subset of them over 2-3 day intervals between October 14 and 30 of 1992, 1993 and 1994. The 1992 sampling was conducted after the fall fertilization which was on Sept. 8, and the latter two, before fall fertilization (November 17 in 1993; no fertilizer applied in fall of 1994). In each year, 20 cores (2.0 cm diameter to 15 cm depth or less as possible) were taken from the four main plot treatments outside of the subplots. Three cores were taken from each subplot sampled. A subsample was frozen for later measurement of pH, EC (electrical conductivity) and nitrate. The rest of the sample was air dried immediately, breaking up clods as the samples dried. In 1992 and 1993, larger particles and recognizable organic debris were removed by hand. In 1994, the samples were passed through a 2 mm sieve. Dried soil samples were sent to A & L Canada Laboratories, London Ontario for analyses of organic matter, P, K, Mg, pH, lime requirement, and estimated CEC. Selected samples were analyzed additionally for S, Zn, Mn, Fe, Cu, and B. This lab uses a Mehlich III extraction for P, K, Mg and Ca, the Walkley Black technique for organic matter, and the SMB buffer to determine lime requirement. The CEC is estimated from data on cations and acidity.

In the winter and spring of 1995, soils from selected treatments for all years were analyzed for Kjeldahl-N in our laboratory using a Tecator Kjeltec system. For these analyses, replicates (450 - 1100 mg samples) were digested with 1.5 g of K_2SO_4 selenium catalyst mixture and 4 mL of H_2SO_4 for 3 hours at 350 ^oC. After cooling and adding 20 mL of water, contents of the digestion tube were steam distilled and 30 mL of the distillate was collected in 5 mL of boric acid. The amount of $NH_4{}^+$-N in the distillate was determined by titrating with 0.01 N H_2SO_4. Total N was expressed as a percent using the relationship that 1 mL of 0.01 N H_2SO_4 equals 0.14 mg of $NH_4{}^+$-N.

For measurement of pH, pHs (pH in salt solution), nitrate and EC (electrical conductivity), 50 or 100 g of thawed soil were shaken with an equal weight of distilled water for 30 minutes. Samples were allowed to settle for 15 minutes, and 5 mL of the supernatant was removed, centrifuged and analyzed for nitrate using "Merckoquant" nitrate test strips (E. Merck, Darmstadt, Germany), which were read in 1993 and 1994 using a "Nitracheck" meter (Hawk Creek Laboratory Ltd., Glen Rock, Pennsylvania). An EC probe was inserted into the supernatant to measure EC and a combination pH probe to measure pH (Patriquin et al., 1993). After the pH measurement, 0.5 or 1.0 mL of 1 M $CaCl_2$ was added, the sample shaken for 10 minutes, and pH again determined.

Biological activity

Fifty grams of soil that had been in an air dried state for two weeks was mixed with 150 g of quartz sand and placed in a one liter Mason jar to which 19 mL water was added. The tops were closed with polyethylene to allow gas exchange but restrict water loss (Bremner, 1965). The jars were incubated at 30 ^{o}C for 7 days and CO_2 evolution measured on day 7-8. Fifty grams of soil + sand were removed for analysis of nitrate and ammonium. Water was added as necessary to bring the moisture up to original values (determined by weight), the jars were recapped and incubated a further 10 days (17 days in total). On day 17, 50 g were taken for analysis of nitrate and ammonium, 6 g for alkaline phosphatase activity (Tabatabai, 1982), and 94 g for measurement of CO_2 evolution with and without glucose. Twenty grams of soil + sand samples were shaken with 10 mL water and analyzed for nitrate. Ammonium was extracted with 2N KCl from three gram soil samples or 12 g soil + sand and determined by distillation and titration using a Tecator Kjeltec System. We did not shake the samples as a comparison of shaken and unshaken samples had indicated that some loss of ammonia occurred during or after shaking.

For measurement of CO_2 evolution in Mason jars on day seven, jars were flushed with a stream of air for two minutes, then a vial containing 10 mL of 0.02 N NaOH was placed in the jar, and the jar was sealed and incubated for six hours. Vials were placed in two jars with no soil in order to determine a background CO_2 correction. Jars were shaken every 35 minutes. Then the vials were removed, closed and capped. Finally they were titrated with 0.02 N H_2SO_4 with a phenolphthalein indicator and CO_2 absorbed was calculated. For the measurements at 17 days, the 90 g samples were split in two, and 45 g samples were placed in one liter Mason jars. To one of the two jars, 1.2 g of glucose-talc (0.2 g glucose and 1.0 g talc) was added. NaOH was added, and jars were incubated as described above except that for the glucose amended jars the incubation time was four hours, the NaOH concentration was 0.01 N, and the CO_2 absorbed was determined by titrating with 0.01 N H_2SO_4.

Respiration, respiration of glucose amended soil, and N mineralization were determined on a set of soil samples taken on Sept. 19, 1995. The set consisted of 20 cores taken throughout each of the four Cn main plots. In this case, the soil was not air dried. The fresh soil was passed through a 2.83 mm mesh sieve, and 50 gram samples of fresh soil were placed in one liter Mason jars. The water content of separate samples of the soils was determined by drying them, and water was added to the soil in the Mason jars to bring the soil up to the estimated field capacity. The water content of the sampled soil was 39% and 44%, for the B and F fields respectively, while their estimated field capacity values were 55.2% and 30.1 % (dry weight soil basis).

Soil depth and bulk density

During the fall, 1994 soil sampling, in each main plot, twenty 2.3 cm diameter coring tubes were inserted into the soil as far as they would go and the depth recorded ("coring depth"). Cores were removed, and the top 15 cm (or less if the soil depth was less than 15 cm) collected. At the lab this material was air dried, and sieved through a 2 mm mesh sieve. Organic debris (roots, thatch), and stones retained on the screen, and the soil passing through the screen were weighed. Bulk density was calculated from the average depth and width (2 cm) of the cores and its dry weight, after correcting for the volume occupied by stones (density 2.6 g cm^{-3}) and organic debris (density 0.25 g cm^{-3}). In the late summer of 1995, soil depth was again measured by inserting a metal rod (0.7 cm diameter) into the soil to the point of strong resistance at 20 sites within each main plot.

Water suction measurements

On June 20, 1995, 5 cm diameter x 5 cm height cores were taken with an Eljkelkamp coring device; the tops were sliced to remove grass crowns, but some thatchy material remained. Five cores from the F field and B field Block 2 BW main plots were sent to the Nova Scotia Dept. Agriculture and Marketing Soils Testing Lab in Truro, N.S. for moisture retention measurements at 0.05, 0.1 0.33, 1 and 15 bars tension. Values for the cores were averaged to give the reported values, minus values for one core in each case which had anomalous high values for water content compared to the other four.

Results

Soil physical properties (measurements made in fall of 1994)

Texture, bulk density, soil depth and stones

- Both fields had relatively thin topsoil layers (Table I2), but these values are typical for urban Halifax where soil is mostly imported.

- B field soil had higher clay and higher silt contents than the F field (Table I2). The B field soil would be classified as a loam, and the F as sandy loam by the USDA system (Gee and Bauder, 1986).

- The B field soil was thicker, had fewer stones and lower bulk density[1] than the F field. It is likely that there was considerable settling of soil after rotovation (B Field), and after the installation of new top soil (F field). Overall, the differences between the B field (Blocks 1,2,3) and the F field (Block 4) in regard to bulk density, soil depth and stones were greater than differences between blocks on the B field.

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[1] Bulk density refers to the weight of a given volume of soil and is commonly presented in units of grams per cubic centimeter or kilograms per cubic meter. In general, organic soils have low values for bulk density while sandy, mineral, compacted soils have high values for bulk density.

- On the B field, there was a trend for the NPK soil to have higher bulk density, measured after three seasons, than other main plot treatments (by Fishers LSD test, NPK differs from Cn, Cp and BW at $\alpha=0.1$).

Estimates of water-holding capacity of B and F field soil

Many of the differences in biological properties that we observed between the B and F fields seemed to be related to greater droughtiness of the F field. When soils differ in texture or structure significantly, water status cannot be compared using % water values because of differences in the soil suction/% water relationships. Generally, soils with more clay and organic matter will have a higher proportion of unavailable water than soils with less (Brady, 1974). Observations were carried out in 1995 to provide a rough characterization of the water holding status of the two fields, and to determine whether mulch versus bag mowing affected water status significantly.

Soil cores (7.5 cm depth) were taken at approximately bi-weekly intervals from mid-May until mid-September from the BW main plot on the F field and from the BW main plot on Block 2 on the B field and their water content determined (Table I3). The values on June 9 were taken one day after cessation of a saturating rainfall, and thus could be considered to roughly represent FC (Brady, 1974) (FC: field capacity, the water content after the larger, gravitational pores have drained leaving only water held by capillary forces and bound water. These values are 40.1% by volume for the B field and 28.0% for the F field).

Larger cores (5 cm diameter by 5 cm depth) taken from the same plots on June 20, 1995, were tested by the Nova Scotia Dept. Agriculture and Marketing Soil Testing Laboratory for percent water after equilibration with different soil suctions. Field capacity generally corresponds to water tensions of 0.1 to 0.33 bars (Gardner, et.al. 1985).

- The percent volume values at 0.33 bars were 48.4% and 37.7% for the B and F field respectively, which are well above the highest moisture values estimated from the field cores.

- Assuming that they are valid, however, and taking the 15 bars values as the PWP (Permanent Wilting Point - water held in soil at this point cannot be extracted by most crop species), the estimated AW (available water: AW=FC-PWP) is 38.6% of volume for the B field and 32.9% for the F field, which is a ratio of 1.17 (B field : F field).

- If the June 9 field values are considered the field capacity values and the 15 bar values the permanent wilting point, then the values are 30.3% of volume for the B field, and 23.2% for the F field, which is ratio of 1.31 (B field : F field).

These estimates suggest the B field had approximately 1.24 times the water holding capacity of the F field in the surface three inches. Considering that the average depth of top soil on the B field was approximately 1.43 times that of the F field, and that rooting in the B field exceeded that of the F field (Section III.1E), it can be concluded that there were significant differences in available water between the two fields, and that the F field was likely to become water stressed before the B field.

- The difference between the June 9, 1995 values and the lowest values observed in 1995 was 13.9% for the B field and 16.0% for the F field (volume basis), which are equivalent to use of 46% and 69% of the estimated available water (by the second method), i.e. the available water reservoirs had fallen by a much greater proportion on the F field than the B field.

Bag mowing/mulch mowing effects on soil water

We wished to determine whether mulch mowing significantly improved the water status of soils compared to bag mowing during periods of water stress. Improved water status could contribute to higher verdure on mulch mowed plots by relieving stress on the grass directly, and/or by relieving stress on the microbes resulting in higher rates of recycling and enhanced nutrient supply.

The bag-mowed treatments initiated in July 1993 were maintained through 1995, and new bag mowed strips were set up in the Cn main plots on the F field and on Block 2 on the B field beginning with the first mowing in early May, 1995. On August 4, 1995, following a week of dry weather, 7.5 cm cores were taken from the original bag mowed/mulch mowed plots and from inside and adjacent to the strips established in 1995. The cores were separated into the top 0-2.5 cm and the bottom 2.5-7 cm, and percent water determined for each separately.

- There were trends of differences for the 0-2.5 cm horizons in the direction expected (lower water content under bag mowing), with differences larger and statistically more significant for the old plots than for the new strips (Table I4) Water content of subsurface horizons did not differ much numerically or statistically for samples inside and outside the strips, or between mulch and bag mowed old plots on the F field; but it did differ for the old plots on the B field (Table I4).

These results suggest that in older mulch mowed plots, higher moisture levels are retained in the surface, thatchy horizon, and in some cases in deeper horizons. The higher surface values could contribute to higher microbial activity, and to improved plant water status. Both are factors which could, in addition to increased nutrient conservation, contribute to the higher verdure and clipping yields that we observed.

Soil chemical properties (except soil organic matter)

The soil chemical data are summarized in four data sets. Quantities of nutrients applied in the amendments are given in Table I5. Table I6 gives data for the Cn, Cp, and BW main plots sampled outside of the area of the subplots, and for the NPK main plots. All main plots were sampled and analyzed separately from subplots in each year (1992, 1993 and 1994). Table I7 gives data for the Cn0 and Cn2 subplots. Figure I1 shows results for all subplot treatments on the Cn main plots in 1994.

In these tables and the figure, statistical test data are given for the B field, except for 1992 in Table I7 when composite samples of Blocks 1-3 were analyzed. Statistical tests include RCB ANOVA's to examine treatment differences within years, and Repeated Measure ANOVA's to determine if values changed significantly over time and whether there were significant differences between treatments when data for three (Table I6) or two (Table I7) years are considered together.

pH and liming effects

- B field soil had a very low pH (circa 4.9) before lime was applied in May of 1992. pH in the fall of 1992 on B field Cn plots (Cn main plot data, Table I6, B field-Cn0 subplot in Table I7) was approximately 0.5 pH units above that of the soil before lime was applied.

- pH on the B field increased by approximately 0.5 pH units over the two years between fall of 1992 and fall of 1994. There were corresponding increases in Mg and Ca (Tables I6, I7) which would have come about through gradual dissolution of the coarse limestone applied in May of 1992.

- Compost (Cp main plot) had a significant liming effect in 1992; pH, Ca, and Mg were all increased by compost (Table I6). The pH, Ca, and Mg contents of compost amended soil was still higher than those of the Cn in the fall of 1994. Other main plot treatments (BW, NPK) appeared to have lowered pH, Ca and Mg relative to the Cn main plot (Table I6), while these values remained about the same as the Cn (Cn0) values on organofertilized plots (Table I7, Fig. I1).

- The imported, F field soil had a near neutral pH before amendments were incorporated. As a commercially produced "top soil", it had been supplemented with fine lime and nutrients before it was imported to the site. pH, Ca and Mg differed less between main plot treatments on the F field than they did on the B field. pH did not change much over the three years, but Ca and Mg exhibited definite trends of decline. pH, Mg and Ca appeared to be increased by organofertilizer on the F field (Table I7, Fig. I1).

Phosphorus

In Table I8, we have calculated the quantities of P and K that were recovered in soil, taking into account soil depth, bulk density and volume occupied by stones. Recovery refers to the amount in plots receiving amendments, minus amount in Cn plots. These values can be compared with the amounts applied, and those amounts minus the amount that we estimate was taken up by vegetation and held in living or dead vegetation at the time of sampling.

- The amount of P incorporated in soil as compost was 5 to 16 fold higher than that incorporated by other treatments (Table I5) and only the Cp treatment effected a statistically significant increase in P in 1992. Brewery waste contained very little P (Table I5), thus only a small increase if any would be expected (Table I8) and that is what was observed (Table I6, I7).

- For most treatments (main plot and subplot), P declined substantially between 1992 and 1993, but not between 1993 and 1994 (Tables I6, I7).

- Although the total addition of P in NPK plots by 1994 was equivalent to nearly half of that contained in the incorporated compost (in the top 10 cm), the soil P values in NPK plots were still not much above Cn plot values. It has frequently been noted that pound for pound, P is more available in compost and manure than it is in superphosphate (Patriquin et al., 1986; Abbott and Tucker, 1973)

- Organofertilizer effected significant increases in soil P in 1994 (Table I7, Fig. I1), but not to the extent that might be expected given the high total P loadings for Cn2 and Cn3 treatments. This may be due to much of the P going into the organic P fraction rather than into the Mehlich III extractable inorganic P fraction.

Potassium

- There were large amounts of K in the compost (Table I5), and the Cp treatment had a significant effect on soil K (Table I6).

- The B field soil was assessed as K deficient prior to incorporations, and 249 kg K was incorporated in the NPK main plots, which also showed a significantly higher K than Cn main plots in 1992 (Table I6), however, the effect was not evident by 1994.

- Only the highest rate of application of organofertilizer appeared to have any significant effect on K reserves (Fig.I1).

- These results make sense when rough estimates are made of the amount of K taken up and held in living and decaying vegetation (Table I8); in 1994, we would predict that only Cp main plot would have a very large excess of K over the Cn main plot.

- For the B field, the difference between the calculated K that should be present in Cp plots in 1994 if there were no losses other than plant uptake (19 kg K), and the actual value (106 kg K), was 85 kg K per ha, which is well within the range that might be expected by leaching loss (Brady, 1974; Frissel, 1977).

The rough estimates of the amount of K that would be taken up by vegetation and held in living and decaying vegetation (Table I8), suggest there should be large soil K deficits in treatments receiving low or no K, i.e. in the absence of renewal of K from non-exchangeable sources, exchangeable K would approach zero and growth would be K limited. This did not happen (Table I6, 1994 values), indicating substantial rates of renewal of exchangeable K from non-exchangeable fractions in the soil.

- The amount of K held in the new turf was estimated (Table I8), as 66 kg K per ha in the first year (two times that held in the verdure to take into account that in roots and decaying vegetation) and 280 kg by the end of 1994 (four times that held in verdure) and likely would have been about 3/4 of the 1994 value in 1993, i.e, 210 kg K per ha.

From 1994 on, we would expect that a reservoir of about 280 kg would be maintained in the living and dead vegetation (these "guesstimates" are for the B field, the F field would lag behind slightly because of low production in 1993).

- The decline of soil K on the Cn main plots (Table I6) between 1992 and 1993, was equivalent to approximately 43 and 52 kg K per ha for the B and F field respectively (calculated for 15 cm depth). The difference (from 210 kg taken up for the B field, and probably circa 125 from the F field) must have been made up by renewal of exchangeable K from the "non-exchangeable" K fraction.

- There was a large decline in K in fertilized plots, and from Cn main plots and Cn0 plots between 1992 and 1993, but levels more or less stabilized between 1993 and 1994 (Table I7). This seems sensible in the light of the estimates of uptake and retention of K in vegetation, i.e. the largest demand for K would have been between 1992 and 1993 because of germination and establishment of the turf. Apparently, the smaller deficits between 1993 and 1994 were completely met by renewal from non exchangeable fractions.

It seems likely that once the system stabilizes, and K is released from living and dead vegetation at rates approximately equal to uptake, that K would have to be applied only to balance leaching losses (in a mulch mowed system), which are probably circa 25 kg K per ha per year or 1/2 lb K_2O per 1000 sq ft or less (Frissel, 1977).

pH, electrical conductivity, and nitrate

Patriquin et al., (1993) proposed that pH, nitrate and EC (electrical conductivity) of 1:1 water extracts of soils can serve as convenient indicators of the degree of "coupling" or "uncoupling" of the soil-plant system. When a system becomes uncoupled or is overloaded with fertilizers, nitrate, EC and acidity typically increase and nutrients can be lost by leaching. When plants take up the free nutrients, the reverse process occurs except that there may be some permanent reduction in soil pH if nitrate was lost in the interim. In a permanent sod system such as turf, these variables would be expected to vary much less than on a farm where cultivated crops are grown and soil-plant coupling is regularly disrupted and then reestablished. However, it was of interest to determine how rapidly these variables change over time in a system going from an uncoupled (the cultivated ground) to a highly coupled (the mature turf) state, and how that change is affected by different treatments. pH, pH in salt solution, EC and nitrate were measured on fresh or frozen soil samples from the fall samplings (Tables I9, I10), and from samples taken on July 16, 1992 and June 11, 1993 (Table I11).

pH

- For the main plots examined in the fall, pH differences were similar to those documented by the commercial lab analyses (Tables I6,I7); pH of Cp plots was 0.3 to 0.4 units higher than values for Cn plots in 1992, but by 1994 there was little or no differences (Tables I9, I10)

- In contrast, pH of BW and NPK plots was progressively reduced over time compared to Cn plots (Table I9) probably due to loss of added N as nitrate (Patriquin et al., 1983).

- Organofertilizer reduced pH on the B field, but increased it on the F field in 1992 (Table I10). In 1993 and 1994, organofertilizer (Cn1,2,3) consistently increased pH compared to no organofertilizer addition, although in most cases only slightly and non-significantly.

It is clear that the organofertilizer does not acidify soil, which can be attributed to it containing sufficient neutralizing material (see values for Ca in Table I5) to counteract any acidification associated with nitrification of the reduced N in the fertilizer (Patriquin et al., 1993)

Electrical conductivity

In a humid region, electrical conductivity provides a measure of the ionic strength of the soil solution, and indirectly of the potential for loss of nutritive ions (nitrate, sulfate, potassium, calcium, magnesium) by leaching (Patriquin, et al., 1993). It is raised for a period after soluble fertilizers are added. Adding urea, although not an ion in itself, can generate high EC when the urea N is nitrified, as nitrification releases hydrogen ions which exchange for nutritive cations (K, Ca, Mg) on the cation exchange complex, bringing them into solution. The process is reversed when the nitrate is taken up by the crop. An excess of organic fertilizer can increase EC by the same mechanism. While low EC will be found in soils of low fertility, it is not necessarily synonymous with low fertility, as a low EC could also be maintained in a system in which nutrients are held mostly in the organic phase or in other insoluble forms, but are continually made available by biological processes.

- EC of Cp plots was significantly higher than that in Cn plots in 1992; by year three it was similar to the Cn plots on the B field but was still high compared to the Cn plot on the F field (Table I9).

- EC of the NPK treatment was slightly elevated in 1992, but not in 1993 and 1994; this is likely because the fall fertilization had been applied in September 1992, but was not applied until after soil sampling in 1993 and 1994.

- On the B field, the BW treatment did not increase EC substantially, while it did so on the F field.

- Overall, F field EC values were higher and differences between treatments were more accentuated than on the B field initially, but all values fell over time (Fig. I3).

Patriquin et al. (1993) observed values of 26-60 uS cm^{-1} in June for hay and pasture sod in the Maritimes that had not received fertilizer within the last month; where sod was broken it increased to 125 to 130 uS cm^{-1}, and where manure was added to the broken ground, to 200 uS cm^{-1}.

- The Cn0 values at The Oaks in the spring of 1995 were 84 and 77 uS cm^{-1} on B and F fields respectively; other treatments appear from the graph to be approaching similar values. The B field soil before disturbance in 1992 had a value of 78 uS cm^{-1}.

We attribute the declines in EC (Fig I3) to leaching loss and to uptake into the organic phase (living and dead) over time of ions that were originally present in excess relative to the nutrient holding capacity. Declines in the Cp treatments could also be related to gradual conversion of the more readily available forms of N in compost to more slowly available forms.

It is interesting that in 1994 (Table I10), the EC of the Cn3 plots on the B field was high relative to other values (141 versus 94 for Cn0 plots), while on the F field, it was lower than all other levels (105 versus 133-170 in other plots including Cn0). Verdure in 1994 was not affected much by level of organofertilizer on the B field, hence you would expect EC to increase with increasing application of organofertilizer. On the F field, there was a large increase in verdure between OF2 and OF3 levels of organofertilizer - this suggests that the relatively low EC value was due to enhanced sequestration of nutrients into living and dead organic matter on the OF3 plots.

These various observations and literature data (Patriquin et al., 1993) suggest that under organic management in this region, mature, closely coupled soil-turfgrass systems will maintain EC values in the region of 100 uS cm^{-1} or less. Where values well in excess (e.g. over 200 uS cm^{-1}) are found, there is likely to be large losses of nutrients during wet weather. These comments are speculative at this stage and more data from different situations and a firmer theoretical understanding of variations are needed, however, it does appear that EC measurements can give some indication of the degree of coupling/uncoupling of nutrient fluxes in the grass soil system. Such measurements could be valuable where it is uncertain whether a system is being overfertilized, e.g. in shady situations where the need for fertilizer supplements may vary considerably according to whether or not trees are competing with the turf for added nutrients.

Nitrate

- Nitrate values in all but one sampling were less than 27 ppm and equivalent to less than 5 kg nitrate-N per ha (10 ppm nitrate = 1.56 kg nitrate-N for B field and 1.89 for the F field in the top 10 cm). The exception was for the July 16, 1992 sampling when biomass was still low (Table I11). Then, high nitrate was observed on the B field, but not on the F field. On the B field, the BW plots had the highest values; Cp main plots had lower values than the Cn main plots, possibly due to immobilization of N.

- In the early June sampling in 1993, the nitrate value for the Cp treatment was slightly above that of the Cn treatment, and the BW values were no longer elevated.

Soil organic matter & soil biological properties

Changes in organic matter and organic-N associated with direct additions of organic matter in amendments

Organic amendments can contribute to soil organic matter by adding organic matter directly to the soil, however very large quantities have to be added to increase soil organic matter by 1% or more. We expected that addition of compost, but not other amendments, would significantly increase soil organic matter, because only compost was adding large amounts of low %N organic matter (Table I5, I12). Brewery waste and the organofertilizer contained much lower amounts of organic matter and they had relatively high %N, thus they would be expected to decompose faster (Mathurs and Goss, 1979).

- Only the compost additions gave a statistically significant increase in soil organic matter on the B field in 1992 (Table I6). There were numerical differences in 1993 and 1994, but they were not statistically significant.

- The calculated apparent recovery of compost organic matter added as soil organic matter in 1992 was 54.0% for the B field, and 49.4% for the F field, using the higher estimates for gain in soil organic matter in Cp treatments in Table I12 which are based on three separate sets of samples.

This suggests that as much as 50% of the compost may have oxidized in the first season. However, it is also possible that the core sampling and analytical subsampling techniques did not properly sample the bulkier organic material added in the compost.

- At the end of 1994, the calculated recovery was 11% for the B field and 16% for the F field, using again the differences in soil organic matter between Cp and Cn plots based on three separate sets of samples. These data, if reliable suggest fairly rapid oxidation of the compost over the three years.

- Visually, compost organic matter was obvious in 1992 in B field soil, but not in 1994, while on the F field, there were still pockets of recognizable compost.

- In contrast to soil organic matter, the 1994 soil N data suggest no loss of soil N added by compost (Table I6, I12). That might in part be due to enrichment of N in soil organic matter as it becomes humified (Jenkinson, 1981).

Changes in organic matter over time due to effects of treatments on production of organic matter by turf and on oxidation of soil organic matter

Soil organic matter may change over time if the system is initially not in equilibrium with respect to soil organic matter (see Box 8). Such changes are likely to be small and difficult to discriminate over a period of only 2-3 years as in these experiments. However, the statistical analyses do suggest there were some significant time dependent changes in soil organic matter (see Repeated Measure Analyses, Tables I6,I7).

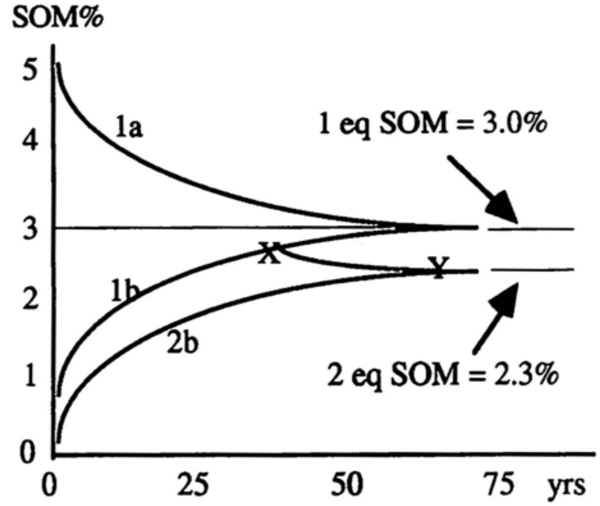
- The main plot data (Table I6) show decreases in soil organic matter for all main plot treatments on the B field between 1992 and 1993 and again between 1993 and 1994. The declines were larger for the Cp, BW and NPK treatments (1.3%) than for the Cn (0.6%).

BOX 8. How much soil organic matter (SOM) can be maintained under turfs?

Soil organic matter (SOM) measured in soil analyses and expressed as a percent of the weight of soil consists mostly of the colloidal, humified organic matter that gives soil its earthy texture and smell. Even if some roots and visible debris are inadvertently included in the sample analyzed, they do not usually add much. To illustrate, for a soil of 3% SOM, there are about 45,000 kilograms of SOM in the top 15 cm of soil, while all living roots might amount to only 5000 kilograms.

Soil organic matter is a dynamic variable, i.e. it is being formed and destroyed continuously, thus the amount present and the changes over time are determined by the balance between the amount of organic matter being added each year from old roots, stems etc., and the amount of SOM broken down by normal soil biological activity. In a humid, temperate climate, 1 to 3% of the SOM breaks down each year. Taking our example above (3% SOM to 15 cm) and a value of 2% per year breakdown, that would amount to 900 kg. That means that to maintain the given level of SOM, 900 kg has to be replaced by new inputs to SOM. If the amount added each year is less than 900 kg, SOM will fall to a new level that is sustainable at the given input; if the amount added is more, SOM will rise to a new level.

Each system or combination of climate, soil type, vegetation and management has an "equilibrium level" of SOM that can be maintained under that regime. For a given soil and climatic regime, this level is determined mainly by how much organic matter is returned to the soil each year - if it is a low amount, the equilibrium level SOM will be low, e.g. 2%; if it is one in which there is a high annual input, it will be high, e.g. 5%.



The figure above shows hypothetical changes in SOM with time. For system 1, the equilibrium SOM level is 3%. If the soil is initially above 3%, it will follow curve 1a down over time; if it is below, it will follow curve 1b. Suppose we have a system which is at point X on curve 1b, i.e. SOM is gradually increasing. Then management changes so that there is less organic matter returned to the soil; that system will now start losing SOM as it moves along the trajectory X-Y towards a new SOM equilibrium of 2.3%.

Whether SOM increases or decreases with a change in management, depends on:

(1) how that change affects net additions of organic matter to SOM,

(2) the rate of breakdown of SOM, and,

(3) how close the initial SOM% value is to the equilibrium value for the management system.

It is difficult to estimate the soil equilibrium value with any accuracy without some rather complicated site specific measurements. However, to get some idea of how fast SOM can change, we estimated the likely range for annual changes in SOM under turf from estimates of the maximum likely and minimum likely values for net additions of organic matter from turf to SOM and for rates of breakdown of SOM:

Table 8.1. Likely ranges for change in SOM and soil N under turf in Nova Scotia, for soils of different initial SOM content.[1]

Initial % SOM	Initial % N	SOM change over 2 years	N change over 2 years
1	0.05	+0.04 to +0.78 %	+0.002 to +0.039 %
3	0.15	-0.08 to +0.74%	-0.004 to +0.037 %
6	0.30	-0.26 to +0.68 %	-0.013 to +0.034 %
9	0.45	-0.43 to +0.62 %	-0.022 to +0.031 %

[1] Estimated from matrix of values generated when it is assumed:

(i) SOM breaks down at rates of 1% (min) or 3% (max) per year,

(ii) net additions to SOM are 500 (min) or 4000 (max) kg ha^{-1} yr^{-1},

(iii) change in SOM = (2 * net annual addition - (loss in yr1+ loss in yr2)/wt of soil x 100) - initial %SOM (Bartholomew and Kirkham, 1960),

(iv) 10^6 kg soil/ha,

(v) %N=1/20 %SOM, and change in N is 1/20 change in OM.

The "net addition" is the amount of organic matter that enters the SOM pool each year and it is equal to the amount of organic matter produced in one year minus the amount of dead, non-humified organic matter broken down in the same year (i.e. some of the organic matter produced is decomposed without entering the SOM pool). In turf, most of the net contribution to SOM will come from old roots, stemmy material, and microbial growth on secretions from living roots. Most of the clippings, which are succulent, decompose fairly quickly. Some may be deposited as thatch (not considered to be SOM), while some of the more resistant material may get worked into the soil through activity of soil fauna and thereby contribute to SOM. We have assumed that the maximum possible contribution is equal to 0.8 x the verdure, which in year 2 at The Oaks was approximately 500 g m^{-2} (hence maximum contribution of organic matter is 400 g m^{-2}). The absolute quantity of roots will be low when total production is low, or under high available N, when both the root to shoot ratio and the absolute quantity of roots decline compared to systems with lower available N (Davidson, 1976). The minimum net contribution to SOM is assumed to be 50 g m^{-2}. Annual rate of breakdown of SOM is assumed to lie within the range of 1-3% (Stevenson, 1986).

The ranges of possible changes in SOM so estimated suggest that at very low SOM (1%) values, growing turf will always increase SOM. However, at values of 3 to 9% SOM, there could be decreases or increases or little or no change according to the particular soil, climate, and management regime. One point to be gained from these figures, is that the annual change in SOM due to grass inputs is generally going to be quite low - only when you are starting with a soil of very low SOM will it change quite rapidly. Adding a lot of compost to a cultivated soil before planting turf is the only way to increase it rapidly.

Another approach to getting a handle on the question of "how much SOM can be sustained under turf?" is to look at actual SOM values for long term turfs or pastures. Patriquin et al. (1986) observed a value of 7.3% SOM for an old grass/legume pasture on a sandy loam soil in Nova Scotia, which can be considered a rough estimate of the maximum possible equilibrium SOM value for organic turfs. In a study of 22 Metro turfs (Hope-Simpson and Patriquin, unpublished), we observed SOM values of 2.20 to 6.10%. Five values were above 5%, and all of these were from long established turfs. Those values (5.1 - 6.1%) probably represent near equilibrium values for Metro turfs. These soils were described as "generally dark brown in color and humid, with a crumbly, well aggregated structure, abundant soil life (insects earthworms, fungal hyphae), and a pleasant, earthy odor." In contrast, SOM values for 28 soils from Crimson Drive - a recent suburban development - were all under 3.5% and were as low as 1%; at least the lower values were probably well below equilibrium values.

Some of the factors that might be expected to influence equilibrium values for turf in Nova Scotia are given below:

<u>Favoring lower values</u>

- sandy soil (favors breakdown of SOM)
- poor soil structure (suppresses roots)
- bag mowing
- strong deficiency of nutrients (low production) and/or excess of N (reduces root growth)
- use of chemicals or other management that inhibit soil fauna

<u>Favoring higher values</u>

- heavier soils
- good soil structure (encourages root growth
- mulch mowing
- adequate nutrients for good growth
- adequate but not excess N
- healthy soil that favors soil fauna (to mix clipping residues into the soil)

- On the F field, the data, to the extent they are representative, suggest no change or gains between 1992 and 1994 in NPK, BW and Cp treatments, and a loss in the Cn treatment. On the Cn0 and Cn2 subplots (Table I7), there were apparent increases in soil organic matter in all treatments from 1992 to 1993 and declines in 1994 to values lower than those in 1992. The magnitude of the changes are in the ranges that are considered possible (see Table in Box 8).

Because the chemical oxidation technique used to determine soil organic matter by the commercial lab is subject to some variation in its efficiency according to the precise procedures (Nelson and Sommers, 1982), we were concerned that these apparent small, but statistically significant year to year changes, could represent analytical differences for different batches of samples analyzed in successive years, rather than real differences. To test differences in the absence of batch differences, we analyzed subsamples of the CnO and Cn2 samples for different years, for soil organic matter by chemical oxidation and total N all in one batch. We included in those analyses composite soil samples from the B and F field taken in May 1992 before the amendments were made and grass sown[2] .

- The results for soil organic matter show no significant time changes, but there was a trend for a reduction in soil organic matter in the Cn2 treatment compared to the Cn0 treatment, which becomes larger with time. On the F field there was no difference between treatments (Fig. I4).

- The repeated measures analysis for N shows no significant treatment effect, but there is a significant time effect for the B field data. However, the differences are significant for 1992 to 1993 (increase), and 1993 to 1994 (decrease), but not for 1992 to 1994. The Time x OF interaction is formally non-significant (p=0.220), but it is clear nevertheless that there was not a decline on the OF0 plots (mean 1992 value: 0.382 %N; 1994: 0.381%N).

We conclude from these data that there is no evidence for decline in soil organic matter in the Cn plots over time, and there may have been some increase. There is a suggestion that the Cn2 treatment reduced soil organic matter compared to the Cn0 treatment on the B field, but not on the F field. When all organofertilizer levels for 1994 (Fig. I1) and the organofertilizer effect for the three years (Table I7) are examined, we see no consistent trend in one direction or the other for either field. Thus we conclude that there was no consistent overall trend of change in soil

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[2] Nitrogen is a structural constituent of humified soil organic matter, typically constituting 5% of soil organic matter. However, the organic matter to N ratio is more variable then the organic matter to C ratio. Organic carbon to total N ratios of topsoils are mostly between 10 and 14. Higher values are found in soils with a lot of partially decomposed plant material and lower values in subsoils (Jenkinson, 1981).

organic matter with time on Cn plots, and that the apparent trends (Tables I5, I6) were artifacts.

The declines in soil organic matter on the Cp, BW and NPK plots (circa 1.3%) on the B field were approximately twice those on the Cn plots (0.6%). The decline in the Cp plot could be reasonably attributed to relatively rapid decomposition of part of the added compost organic matter while what remains after three years would be expected to be well humified (Mathurs and Goss, 1979). Brewery waste organic matter would be expected to decompose almost completely over this period, and presumably accounted for much of the apparent decline on BW main plots.

In the case of the NPK main plots, the decline, if real would have to be due to enhanced breakdown of native soil organic matter and/or lower production of substrates such as roots for production of new soil organic matter, compared to the unfertilized Cn plots. Such effects of excess N are known (Jenkinson, 1981).

Soil biological activity

Several variables relating to soil microbial biomass and microbial activity were measured on soil samples taken in 1994 (Table I13). Such variables have been found to exhibit measurable changes over the short term that are correlated with longer term changes in soil organic matter and quality (Sparling, 1992). Alkaline phosphatase activity (P-ase) and CO_2 evolution in glucose amended soil are generally found to be highly correlated with soil microbial biomass (e.g. Frankenberger and Dick, 1983). Our measurements were made on air dried soil that was rewetted and "preincubated" at 30 ^oC for seven days prior to measuring respiration, and for a further 10 days (total 17 days) prior to measuring respiration in glucose amended soil, alkaline phosphatase activity, and total inorganic N. Approximately 14 days are required for rewetted air dried samples from this region to attain a stable level of microbial activity at 30 ^oC (Patriquin et. al., 1986).

- For the B field, compost increased the two measures of soil microbial biomass (P-ase and CO_2 in glucose amended soil) significantly.

- Respiration measured at seven days was lowered significantly in the NPK treatments compared to the Cn treatment. NPK main plot values for P-ase activity, respiration + glucose, and total inorganic N were also lower than Cn main plot values (no organofertilizer).

The lower values for the NPK treatment in combination with the numerical decline in soil organic matter referred to above and the increased bulk density of the NPK plots compared to others, suggest there was a real decline in overall soil quality on these plots compared to the Cn main plot.

- On the F field, P-ase and CO_2 values were highest for the Cp main plot, and appeared to be stimulated by organofertilizer. The NPK value was above that of the Cn treatment for P-ase, but less than the Cn treatment for CO_2. The CO_2-glucose values did not differ much between treatments overall.

- On the F field, all organofertilizer treated subplots had higher values for all variables than the Cn0 subplots.

- Values for total inorganic N, or inorganic N produced during the incubations did not show large variations between treatments on the B field or meaningful trends. For the F field, there was less total inorganic N on BW and NPK plots than on Cp and Cn main plots, and there was a general trend for increasing inorganic N or mineralized N with increasing level of organofertilizer.

Overall, there is a fairly high degree of concurrence between these variables within the B field or within the F field, with highest values on Cp main plots in both fields, lowest values on the B field in the NPK plots, and on the F field in the Cn plots. There were no consistent trends for different levels of organofertilizer on the B field, and consistently higher levels in organofertilized plots (Cn1,2,3) compared to the Cn0 plot on the F field.

Soil samples from bag mowed and OF3X (fertilized with 3 lbs N per annum with organofertilizer, but none applied in 1994) plots were also examined for soil biological activity.

- P-ase on the bag mowed plots was lower than that of all other treatments for the B field, and equal to the Cn treatment for the F field. The value for the Cn3X plot was higher than all other values for the B field, and lower for the F field. Curiously, mineralized N for the bag mowed plot was significantly higher than the value for the mulch mowed equivalent (Cn1) on the B field.

Overall, values for the various processes were in the same range for both fields. We had expected the B field values to be significantly higher because of the higher soil organic matter, and other characteristics related to soil quality. Soil-sand-water mixtures (1:3:0.37 soil:sand:water by weight) were used in these assays. The ratio used is one suggested by Bremner (1965) to give optimal conditions for a wide range of soils, however, we noted that the F field mixtures were cohesive, while those for the B field were loose, suggesting that the B field systems had significantly lower water tensions, and therefore might not have been properly comparable with the F field. After determining the approximate field capacity values for the two fields in 1995, we compared respiration, respiration with glucose and N mineralization in fresh soil (not air dried and rewetted as in the 1994 set) from Cn main plots at their approximate field capacities (Table I14).

- The F field values so determined were less than any of the values for Blocks 1-3. The averages for the B field blocks exceeded the F field values by factors of 1.5, 1.7 and 3.0 for respiration, respiration with glucose, and mineralized N respectively. These factors are close to the factors for soil organic matter and soil N in 1994 which were 2.1 and 4.2 respectively (averages for B and F Cn main plot and Cn0 values from Tables I6, I7).

- The assays in 1995 were run at 22 ^{o}C to enable estimation of soil microbial biomass from respiration in glucose amended soil (Anderson and Domsch, 1978), which is estimated to be 61.4 and 36.3 mg microbial C 100 g soil^{-1} for the B and F fields respectively.

These values represent 2.5% and 3.1% of total carbon where the latter is estimated from the soil organic matter values (Table I6, I7) assuming C is 0.5 x soil organic matter. These percentages are within the range generally reported for soils (1-5%; Sparling (1992)). They are approximate values however, as the test was not specifically calibrated for these soils, and the estimate of soil C is approximate.

Earthworms

Numbers of earthworms were counted in cores taken from the Cn main plots in the fall of 1994. Data were square root transformed for ANOVA.

- There were no statistically significant or suggestive numerical trends between subplots (i.e. different levels of organofertilizer, bag mowing vs. mulch mowing).

- The F field cores contained much lower numbers of worms (average 0.65 worms per 10 cores) than the B field cores (averages of 2.09, 3.62, and 1.98 worms per 10 cores for Blocks 1, 2, and 3 respectively).

Supplementary data on effects of bag mowing on soil variables

Data for bag mowed plots in the Cn main plots are given in Fig. I1. We also obtained soil data for bag mowed plots in the Cp and NPK main plots.

- There were no significant interaction effects between the main plot (Cn, Cp, NPK) and subplot (mulch mowed or bag mowed) on the soil variables (Table I15).

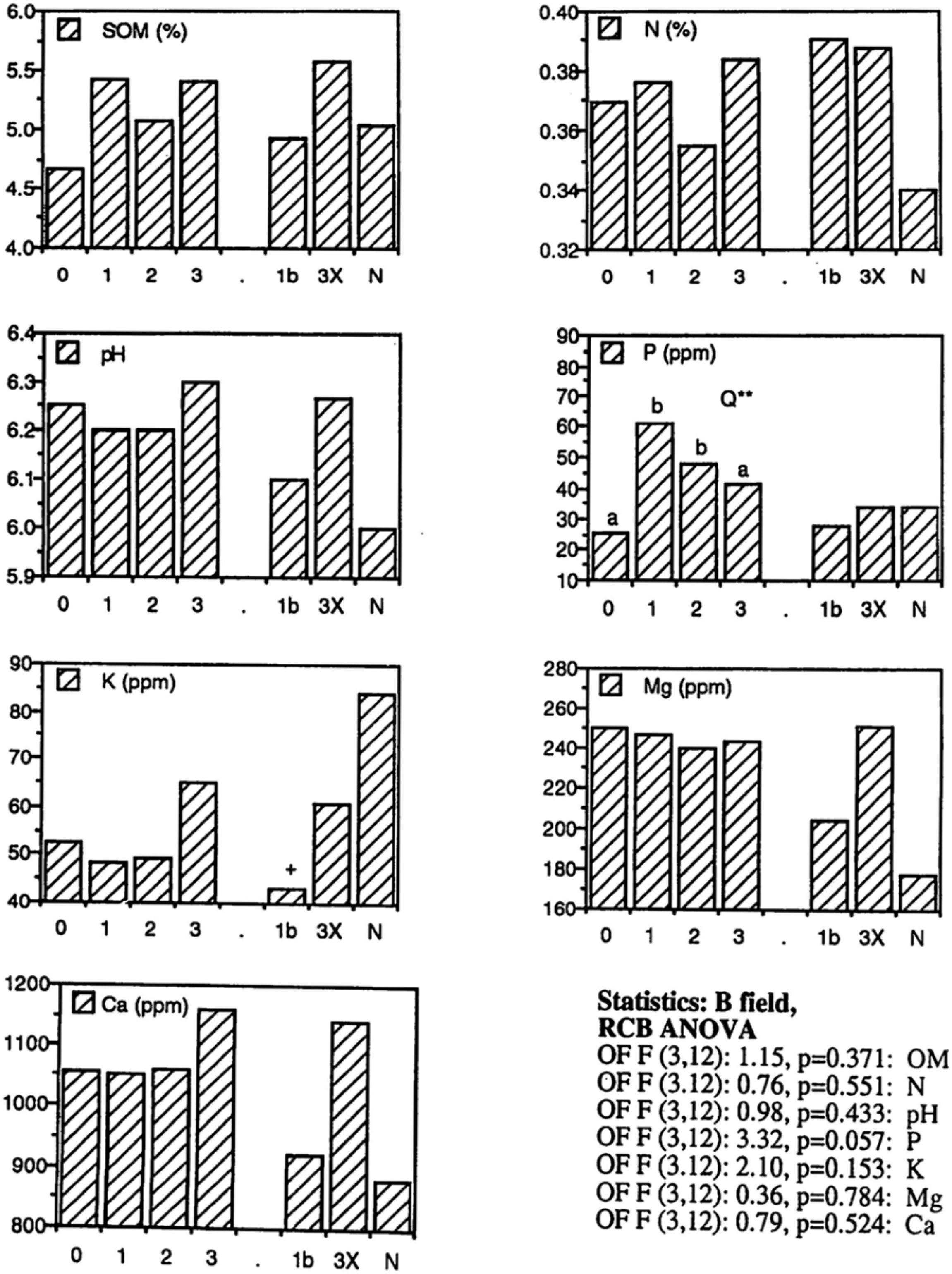
- Although most values for the bag mowed plots were less than those for mulch mowed plots, differences were not in most cases large or statistically significant, except for soil organic matter on the F field (reduced by 1% in bag mowed plots) and EC on the B field (95 in bag mowed versus 120 uS cm^{-1} in mulch mowed plots).

The apparent decline in soil organic matter on the F field was large (1%), and suggests that removing clippings on this field was sufficient to reduce the equilibrium organic matter level well below the current level of organic matter.

Supplementary data on effects of stopping organofertilizer use in the third year on soil variables

Data on 3X treatments (subplots to which organofertilizer was applied at 3 lbs N level in 1992 and 1993 but none was applied in 1994) in the Cn main plots are given in Fig. I1. We also obtained soil data for 3X treatments in the BW main plots. Results of statistical analyses for the combined data (Cn and BW main plots) are given in Table I16.

- Interrupting application of organofertilizer in the third year of the experiment appeared to have no substantive or statistically significant effects on organic matter, P, K, Ca, or Mg.



Statistics: B field,
RCB ANOVA

OF F (3,12): 1.15, p=0.371: OM
OF F (3.12): 0.76, p=0.551: N
OF F (3,12): 0.98, p=0.433: pH
OF F (3,12): 3.32, p=0.057: P
OF F (3.12): 2.10, p=0.153: K
OF F (3,12): 0.36, p=0.784: Mg
OF F (3,12): 0.79, p=0.524: Ca

Figure I1. Soil values for different levels of organofertilizer for the B field in 1994.

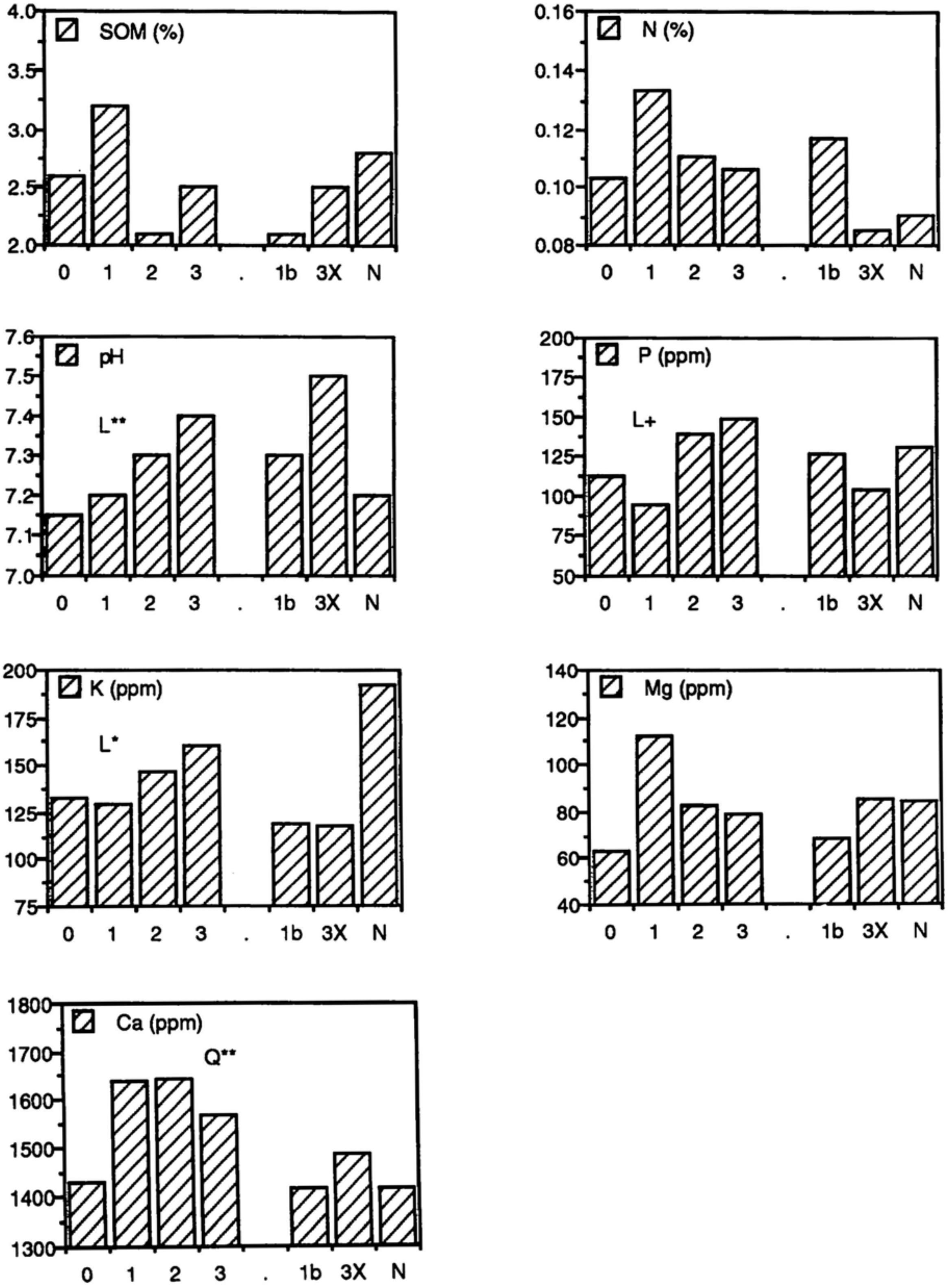


Figure I2. Soil values for different levels of organofertilizer for the F field in 1994.

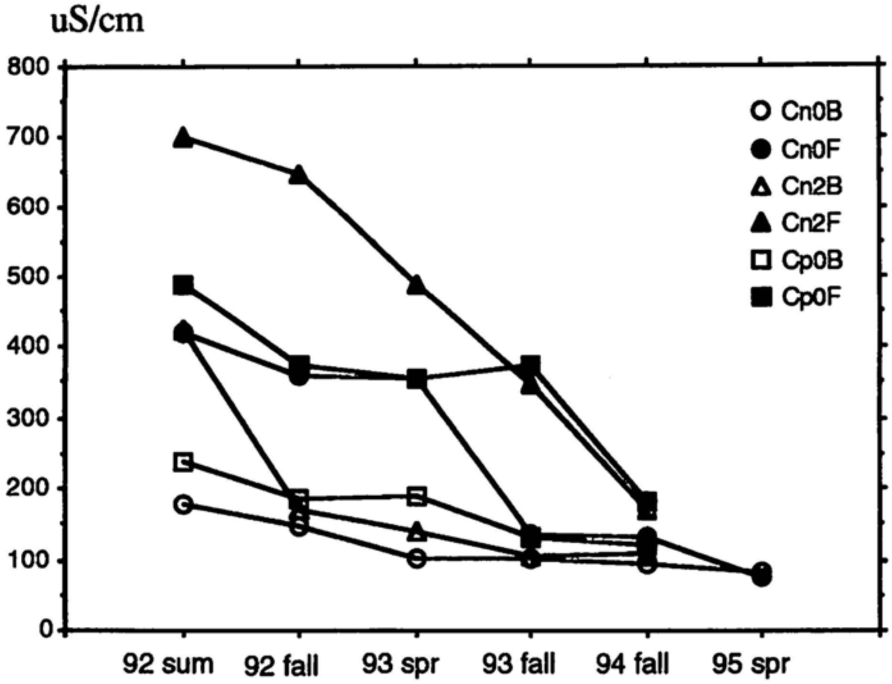


Figure I3. Electrical conductivity of 1:1 water:soil extracts for selected treatments at successive samplings

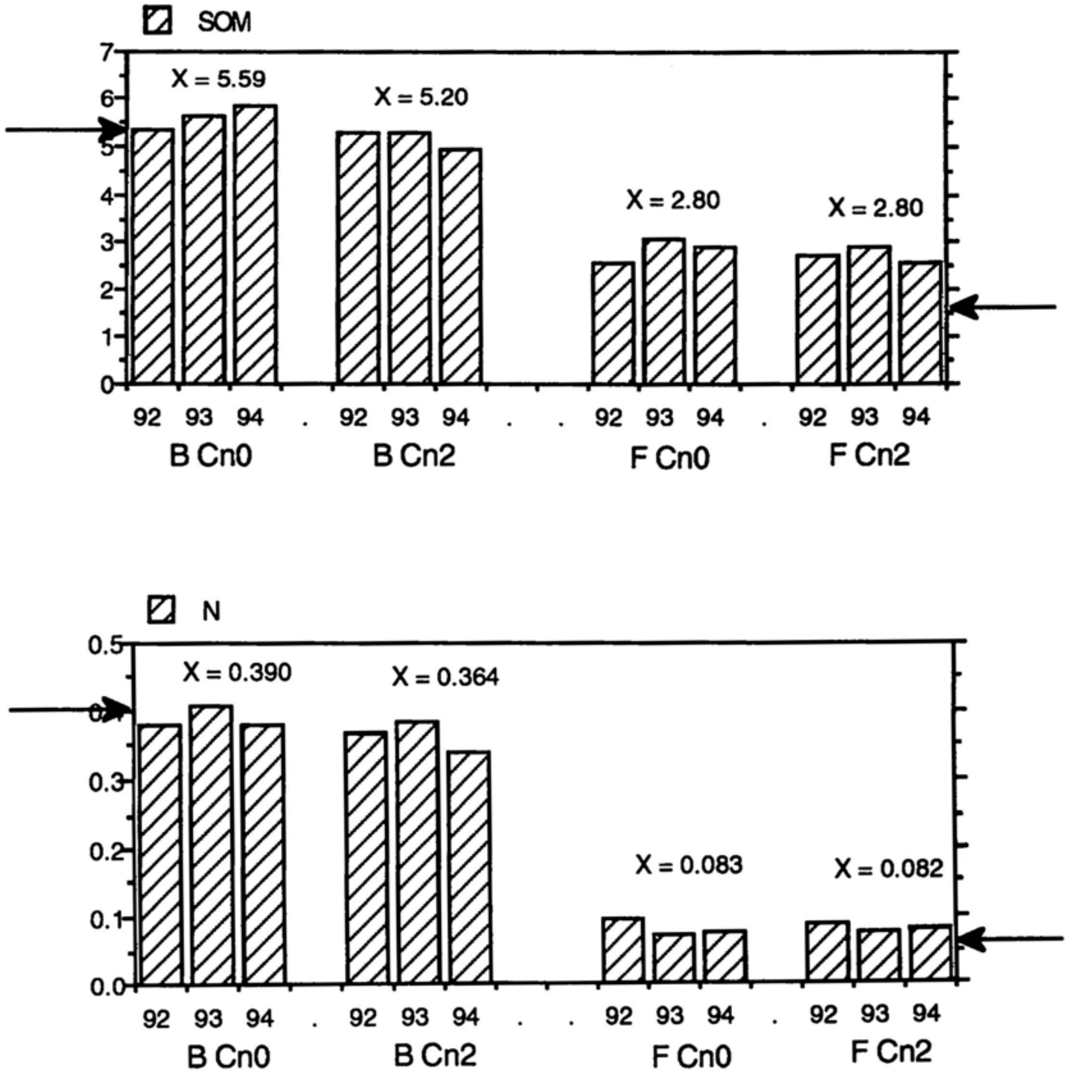


Figure I4. Soil organic matter (%) and total N (%) of soil samples from different years analyzed in one batch. Arrows show values for samples of B field soil (left) and F field soil (right) taken before any amendments were made.

Statistics: B field, Repeated Measures

	Organic Matter	**Total N**
Organofertilizer	F (1,2) = 12.5 p=0.071	F (1,2) = 0.83 p=0.046
Time	F (2,4) = 0.39 p=0.699	F (2,4) = 14.9 p=0.014
Time * OF	F (2,4) = 2.17 p=0.230	F (2,4) = 2.26 p=0.220

Table I1. Potential indicators of improved soil quality (from Granatstein and Bezdicek, 1992).

Improved Soil Quality Indicated by *Increasing*:	
infiltration	water holding capacity
macropores	aggregate stability
aeration	soil organic matter
biological activity	
Improved Soil Quality Indicated by *Decreasing*:	
bulk density	soil resistence
runoff	diseases
erosion	production costs
nutrient losses	

Table I2. Soil depths and bulk densities determined in the fall of 1994 (except soil depth with rod; determined in summer of 1995). The values for quantity of soil (t per ha) refer to material finer than 2 mm.

Blk	**Main Plot**	**Avg. Depth of Soil** core (cm)	rod (cm)	**Bulk Density** (g cm^{-3})	**Stones** (% volume)	**Quantity of Soil** (t ha^{-1})
1	Control	10.0	20.9	0.813	13.7	691
1	Compost	10.5	20.4	0.819	11.2	740
1	Spent Grain	10.1	19.8	0.821	16.4	680
1	NPK	10.1	24.2	0.946	14.5	788
2	Control	10.1	20.4	0.792	7.8	698
2	Compost	10.7	28.0	0.776	8.4	726
2	Spent Grain	9.4	25.5	0.727	11.4	570
2	NPK	10.4	19.1	0.834	10.5	758
3	Control	12.0	22.4	0.758	6.4	829
3	Compost	12.0	22.1	0.700	11.9	729
3	Spent Grain	11.1	25.4	0.824	4.0	850
3	NPK	14.4	19.8	0.805	7.7	1028
4	Control	10.0	15.4	1.097	15.8	895
4	Compost	7.1	15.7	1.031	12.5	597
4	Spent Grain	7.2	13.9	0.930	20.0	532
4	NPK	6.2	14.8	1.054	15.7	534
B avg		10.9	22.3	0.801	10.3	757
F avg		7.63	14.9	1.028	16.0	640
B	control avg			0.788		
B	compost avg			0.765		
B	BW avg			0.791		
B	NPK avg			0.862		
	(F(2,3): 2.68 p=	0.140)				
Blk 1	avg (all MP)			0.850		
Blk 2	avg (all MP)			0.782		
Blk 3	avg (all MP)			0.772		
Blk 4	avg (all MP)			1.028		

B texture:	sand 49.5%	silt 34.3%	clay 16.2%
F texture:	sand 68.9%	silt 22.9%	clay 8.2%

Table I3. Percent water and temperature in soil in 1995, and percent water in soil cores held at different water suctions.[1]

	%Water				Soil Temperature[2]	
	B field		F field		B field	F field
Date	%DW	%vol	%DW	%vol	°C	
May 18, 1995	54.3	39.5	36.5	33.9	12.1	12.8
June 2, 1995	44.7	32.5	23.8	22.1	17.0	19.2
June 9, 1995	55.2	40.1	30.1	28.0	18.5	19.2
June 23, 1995	56.0	40.7	31.1	28.9	23.7	25.2
July 7, 1995	49.4	35.9	31.4	29.2	25.2	25.6
July 21, 1995	52.0	37.8	30.3	28.2	24.3	25.0
Aug. 4, 1995	48.8	35.5	29.3	27.2	25.2	25.6
Aug. 11, 1995	47.0	34.2	29.7	27.6	No Data	
Aug. 18, 1995	49.1	35.7	26.6	24.7	23.2	21.6
Sept. 2, 1995	36.1	26.2	17.4	16.2	20.7	20.3
Difference Jn 9/Sp2	19.1	13.9	17.2	16.0		
Water tension (bars)						
0	102.9	71.9	58.6	57.6		
0.05	79.6	55.6	45.1	44.1		
0.1	73.6	51.5	43.5	42.9		
0.33	69.3	48.4	38.3	37.7		
1	62.3	43.6	32.6	32.2		
15	14.0	9.8	4.9	4.8		
Diff 0.33/15 bars	55.3	38.6	33.4	32.9		
Diff Jn 9/15 bars	41.2	30.3	25.2	23.2		

1. %DW data were converted to volume basis assuming BD of 0.727 for B field-B12 BW and 0.930 for F field (Table I2). For the water tension values which are averages for 4 core samples, the avg BD was 0.700 for the B samples and 0.990 for the F samples.

2. Temperatures are averages for three readings at 2.5 cm depth.

Table I4. Water content (% of dry weight of soil) of soil cores taken from bag mowed and mulch mowed plots.

Field & Treatment	%H_20 mulch	%H_2O bag	Statistical Tests
F field, strip			
0-2.5 cm	24.9	22.2	paired t test (n=10), p=0.143
2.5-7.5 cm	16.3	15.8	paired t test (n=10), p=0.416
B field, strip			
0-2.5 cm	49.2	45.1	paired t test (n=10), p=0.130
2.5-7.5 cm	37.6	37.8	paired t test (n=10), p=0.956
F field, old plots (4 pairs)			
0-2.5 cm	36.7	28.8	F(1,3): 5.54, p=0.100
2.5-7.5 cm	22.1	20.2	F(1,3):0.541, p=0.515
Bfield, old plots (12 pairs)			
0-2.5 cm	60.8	50.3	F(1,8):4.40, p=0.069
2.5-7.5 cm	41.2	35.4	F(1,8):4.35, p=0.071

Table I5. Quantities of organic matter, N ,P, K, Mg, and Ca applied in amendments over the interval May 20, 1992 to November 1, 1995.

Amendment	Component	Incorporated (kg/ha)	Top Dressed (kg/ha)	Total (kg/ha)
Compost	OM	31450	0	31450
Brew Waste	OM	7310	0	7310
NPK	OM	0	0	0
OF1	OM	464	928	1392
OF2	OM	929	928	1857
OF3	OM	1393	2786	4179
Compost	N	589	0	589
Brew Waste	N	470	0	470
NPK	N	100	300	400
OF1	N	50	100	150
OF2	N	100	200	300
OF3	N	150	300	450
Compost	P	500	0	500
Brew Waste	P	50	0	50
NPK	P	65	98	164
OF1	P	28	60	89
OF2	P	59	119	178
OF3	P	89	178	267
Compost	K	706	0	706
Brew Waste	K	38	0	38
NPK	K	249	201	450
OF1	K	40	80	120
OF2	K	80	160	240
OF3	K	120	240	360
Compost	Mg	353	0	353
Brew Waste	Mg	23	0	23
NPK	Mg	0	0	0
OF1	Mg	1.8	3.5	5.3
OF2	Mg	3.5	7.0	10.6
OF3	Mg	5.3	10.6	15.8
Compost	Ca	1178	0	1178
Brew Waste	Ca	42	0	42
NPK	Ca	0	0	0
OF1	Ca	124	249	373
OF2	Ca	249	498	746
OF3	Ca	373	746	1120

Table I6. Chemical characteristics of soils sampled in the fall of 1992, 1993, and 1994. Values for the B field are averages for three Blocks.

Main Plot	SOM (%)			N%	pH		
	1992	1993	1994	1994	1992	1993	1994
B Cn	5.87	5.80	5.30	0.37	5.47	5.83	6.17
B Cp	6.93*	6.37	5.67	0.43*	5.80*	5.93	6.27
B BW	6.40	5.87	5.13	0.37	5.40	5.57*	6.06
B NPK	6.33	5.17	5.03	0.34	5.50	5.63	6.00
F Cn	3.1	3.60	2.10	0.10	6.90	7.00	6.90
F Cp	3.5	4.10	3.70	0.16	7.00	7.20	7.20
F BW	2.9	3.50	3.20	0.12	6.90	7.00	7.20
F NPK	2.8	3.40	2.80	0.09	7.00	7.00	7.20
B ANOVA							
F (3,6)	2.69	2.92	0.63	7.54	5.38	5.25	2.33
p	0.14	0.12	0.62	0.02	0.04	0.04	0.17
cv	7.23	8.60	11.4	6.45	2.42	2.27	2.13
B Rep. meas.	(all years)				(all years)		
MP	F (3,6): 2.41, p=0.165				F (3,6): 4.69, p=0.051		
Time	F (2,12): 20.1, p <0.0001				F (2,12):188, p =0.0001		
Time*MP	F (6,12): 1.12, p = 0.405				F (6,12): 2.91, p = 0.055		

Main Plot	P (ppm)			K (ppm)			Mg (ppm)		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
B Cn	38.7	45.3	24.7	78.7	37.0	46.7	171	201	245
B Cp	274**	122**	153**	380**	231**	200**	246**	213	265
B BW	41.3	27.0	25.7	70.3	46.3	53.0	189	158**	223
B NPK	68.0	55.0	33.7	103**	84.3**	84.0	167	138**	178*
F Cn	153	126	80.0	136	95.0	111	133	87.0	65
F Cp	278	149	212	335	221	197	224	141	108
F BW	129	103	80	140	120	147	154	115	92
F NPK	200	102	130	289	166	192	123	95.0	84
B ANOVA									
F (3,6)	6.38	8.43	8.85	190	141	15.1	5.97	21.7	5.73
p	0.03	0.01	0.01	0.00	0.00	0.00	0.03	0.00	0.03
cv	73.5	39.7	61.4	10.5	13.1	33.2	13.5	7.35	11.9
B Rep.meas.	(all years)			(all years)			(all years)		
MP	F (3,6): 8.26, p=0.015			F (3,6): 112, p=0.0001			F (3,6): 15.1, p=0.003		
Time	F (2,12):7.02, p =0.010			F (2,12): 66.3, p =0.0001			F (2,12): 17.3, p <0.0003		
Time*MP	F (6,12): 3.72, p = 0.025			F (6,12): 12.9, p = 0.0001			F (6,12): 2.03, p = 0.139		

Main Plot	Ca (ppm)			CEC			%BS		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
B Cn	792	954	1364	15.2	14.2	13.0	37.1	46.3	62.9
B Cp	1549**	1308*	1471+	19.2**	15.7+	13.7	56.2	56.8+	73.4
B BW	850	733+	966+	16.8	14.7	12.0	36.1	34.8*	57.3
B NPK	832	732+	883*	16.0	14.2	12.1	37.6	35.4*	51.0+
F Cn	1683	1589	1209	11.6	10.2	8.1	85.3	87.3	85.1
F Cp	1766	1810	1358	13.3	11.3	8.6	87.2	95.6	95.3
F BW	1816	1709	1376	12.5	11.3	8.4	85.6	86.7	95.3
F NPK	1735	1545	1414	12.0	10.2	8.7	86.7	87.3	95.4
B ANOVA									
F (3,6)	31.0	14.0	10.1	5.21	1.83	1.71	15.1	11.6	5.35
p	0.00	0.00	0.01	0.04	0.24	0.26	0.00	0.01	0.04
cv	11.2	13.5	13.5	7.76	6.29	8.21	10.3	12.2	11.7
B Rep.meas.	(all years)			(all years)					
MP	F (3,6): 36.6, p=0.0003			F (3,6): 3.73, p=0.080					
Time	F (2,12): 8.71, p <0.004			F (2,12): 71.9, p=0.0001					
Time*MP	F (6,12): 2.64, p = 0.072			F (6,12): 2.37, p = 0.096					

Table I6. Concluded.

Main Plot	%K			%Mg			%Ca		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
B Cn	1.33	0.68	0.93	9.43	11.8	15.7	26.3	33.7	46.2
B Cp	5.06	3.77	3.67	10.7	11.3	16.9	40.4	41.7	53.7
B BW	1.07	0.80	1.13	9.43	8.97	15.6	25.6	25.0	40.5
B NPK	2.63	1.53	1.80	8.73	8.13	12.4*	26.2	25.7	36.8
F Cn	3.00	2.40	3.50	9.60	7.10	6.70	72.7	77.8	74.9
F Cp	6.50	5.00	5.90	14.1	10.4	10.5	66.6	80.1	79.0
F BW	2.90	2.70	4.50	10.2	8.50	9.10	72.5	75.5	81.7
F NPK	6.20	4.20	5.70	8.50	7.70	8.10	72.0	75.4	81.6

Main Plot	%H		
	1992	1993	1994
B Cn	62.9	53.7	37.1
B Cp	43.8	43.2	26.6
B BW	63.8	65.2	42.7
B NPK	62.4	64.6	49.0
F Cn	14.7	12.7	14.9
F Cp	12.8	4.40	4.70
F BW	14.4	13.3	4.70
F NPK	13.3	12.7	4.60

Table I7. Chemical characteristics of soils sampled in the fall of 1992, 1993, 1994. Values for the B field are averages of three Blocks.

Subplot	OM (%)			N%			pH		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
B Cn0	5.3	6.0	4.7	0.382	0.406	0.381	5.20	5.83	6.25
B Cn2	5.4	5.8	5.1	0.367	0.384	0.340	5.20	5.93	6.20
F Cn0	2.7	2.9	2.6	0.097	0.074	0.077	6.60	6.90	7.15
F Cn2	2.5	3.4	2.1	0.088	0.075	0.082	6.80	7.10	7.30
B ANOVA									
F (1,2);93 (1,8);94		0.08	1.09	0.625	0.224	0.122		3.00	0.75
p		0.80	0.33	0.512	0.601	0.313		0.22	0.41
cv		14.6	14.2					1.20	1.60

B Rep. meas.	(93/94)	(92/93/94)	(93/94)
OF	F (1,2): 0.03, p=0.879	F (1,2): 0.83, p=0.458	F (1,2): 3.00, p=0.225
Time	F (1,2): 114, p=0.009	F (2,4): 14.9, p=0.014	F (1,2): 26.7, p=0.035
Time*OF	F (1,2): 10.3, p=0.085	F (2,4): 2.26, p=0.220	F (1,2): 1.28, p=0.374

Subplot	P (ppm)			K (ppm)			Mg (ppm)		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
B Cn0	55.0	61.0	25.7	85.0	40.0	52.7	155	201	250
B Cn2	59.0	47.3	47.5*	97.0	36.7	49.3	147	204	240
F Cn0	135	119	112	154	110	133	109	86.0	63.0
F Cn2	145	100	139	233	130	147	139	101	82.0
B ANOVA									
F (1,2);93 (1,8);94		0.33	5.34		0.27	0.26		0.03	0.75
p		0.62	0.05		0.65	0.62		0.87	0.41
cv		54.1	44.7		20.3	22.0		10.9	8.13

B Rep meas.	(93/94)	(93/94)	(93/94)
OF	F (1,2): 0.06, p=0.816	F (1,2): 0.57, p=0.527	F (1,2): 0.09, p=0.789
Time	F (1,2): 3.72, p=0.193	F (1,2): 8.66, p=0.098	F (1,2): 16.2, p=0.056
Time*OF	F (1,2): 3.79, p=0.191	F (1,2): 0.00, p=1.000	F (1,2): 0.39, p=0.592

Subplot	Ca (ppm)			CEC			%BS		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
B Cn0	745	952	1056	14.8	12.9	12.0	35.3	50.9	64.1
B Cn2	735	937	1058	15.9	13.3	12.8	32.3	48.8	59.1
F Cn0	1306	1770	1430	9.8	11.5	8.6	79.7	85.3	93.1
F Cn2	1641	1948	1643	12.0	12.0	9.3	83.3	90.8	99.9
B ANOVA									
F (1,2);93 (1,8);94		0.10	0.00		0.30	7.11			
p		0.78	0.99		0.63	0.03			
cv		5.78	12.1		6.20	4.37			

B Rep.meas.	(93/94)	(93/94)
OF	F (1,2): 0.01, p=0.933	F (1,2): 3.16, p=0.217
Time	F (1,2): 12.7, p=0.071	F (1,2): 3.06, p=0.222
Time*OF	F (1,2): 0.06, p=0.827	F (1,2): 0.32, p=0.626

Subplot	%K			%Mg			%Ca		
	1992	1993	1994	1992	1993	1994	1992	1993	1994
B Cn0	1.50	0.77	1.20	8.70	13.1	17.8	25.1	37.1	45.1
B Cn2	1.60	0.73	1.03	7.70	12.7	16.1	23.0	35.3	42.0
F Cn0	4.00	2.40	3.95	9.20	6.20	6.10	66.4	76.6	83.1
F Cn2	5.00	2.80	4.05	9.70	7.00	7.40	68.6	81.1	88.5

Subplot	%H		
	1992	1993	1994
B Cn0	64.7	49.1	35.9
B Cn2	67.7	51.2	40.9
F Cn0	20.3	14.7	6.85
F Cn2	16.7	9.2	0.05

Table I8. Calculated recovery of applied P and K as extractable soil nutrients in the fall of 1992 and 1994. Units are kg per ha elemental P and K.

Trt.	Nutr	kg incorp. May '92		Rec.[2] Fall '92		kg top dress all years	kg added top 10 cm all yrs		Rec.[2] to 10 cm fall '94	
		Appl	Appl-up[1]	B	F	B/F	Appl	Appl-up[1]	B	F
Cp	P	500	488	245	158	0	333	253	89	111
BW	P	50	40	3	-30	0	33	-47	1	0
NPK	P	66	56	31	59	99	142	62	6	42
Cn1	P	30	20	•	•	60	79	-1	25	-16
Cn2	P	59	49	4	13	119	158	78	15	23
Cn3	P	89	79	•	•	178	237	157	11	31
Cp	K	706	640	314	251	0	471	191	106	72
BW	K	38	-28	-9	5	0	25	-255	4	30
NPK	K	249	183	88	193	201	367	87	26	68
Cn1	K	40	-26	•	•	80	107	-173	-3	-3
Cn2	K	80	14	13	0	160	213	-67	-2	12
Cn3	K	120	54	•	•	240	320	40	9	24

1 Amount applied minus amount held in vegetation and decomposing vegetation. The latter was estimated as two times (1992) and four times (1994) the quantity of nutrient held in the verdue, which assumed for both fields to be 150 $g\ m^{-2}$ (1992) and 500 $g\ m^{-2}$ (1994), with 0.4% P in both years, 2.2%K in 1992 and 1.4% K in 1994.

2 Recovery is calculated as the amount in the soil from the treatment plot minus amount in the Cn main plot (for Cp, BW and NPK treatments) or Cn0 plots (for the Cn1,2,3 treatments). It is assumed that fertilizers were incorporated initially to 15 cm, while top-dressed fertilizers were held within the top 10 cm which is also the approximate average coring depth in 1994, i.e. fertilizers added to soil would be diluted through the top 10 cm when cores were mixed and subsampled following the final sampling. Quantities of soil assumed in order to calculate kg per ha from ppm soil data are those given in Table I2, corrected for presence of stones and calculated for 10 or 15 cm depth (quantity to 10 cm depth: 694 t/ha B field and 841 t/ha F field).

Table I9. Main plot (outside of subplots) values of pH, pH in salt solution, EC (electrical conductivity) and nitrate in the fall sampling. Units are uS cm^{-1} for EC and mg L^{-1} for nitrate.

B Field

	pH			pH salt		
	1992	*1993*	*1994*	*1992*	*1993*	*1994*
Control	5.50	6.12	6.07	5.23	5.35	5.60
Compost	5.92*	6.18	5.97	5.67*	5.45	5.70
B. Waste	5.83	5.82*	5.83*	5.33	5.08*	5.50+
NPK	5.53	5.83*	5.67+	5.27	5.15+	5.40
F (3,6)	9.88	7.58	5.40	5.56	7.63	4.00
P	0.01	0.018	0.039	0.036	0.018	0.070

	EC			Nitrate		
	1992	*1993*	*1994*	*1992*	*1993*	*1994*
Control	96.0	107	120	1.33	11.3	7.3
Compost	185*	133+	123	1.67	12.3	6.0
B. Waste	107	111	133	3.33	8.7	9.0
NPK	147+	111	118	10.7*	7.3	1.0
F (3,6)	7.06	2.38	0.34	3.98	0.91	1.00
P	0.022	0.169	0.800	0.071	0.488	0.455

F Field

	pH			pH$_{salt}$		
	1992	*1993*	*1994*	*1992*	*1993*	*1994*
Control	6.70	7.30	6.50	6.60	6.55	6.30
Compost	7.00	7.20	6.50	6.85	6.50	6.50
B. Waste	6.75	7.10	6.70	6.70	6.50	6.40
NPK	6.50	7.20	6.50	6.25	6.35	6.40

	EC			Nitrate		
	1992	*1993*	*1994*	*1992*	*1993*	*1994*
Control	200	128	132	10.0	6.0	17.0
Compost	375	375	181	7.0	20.0	0.0
B. Waste	300	310	163	6.0	5.0	2.0
NPK	375	220	169	12.0	22.0	1.0

+, *, denote significant differences from Control at $\alpha = 0.1$ and 0.05 respectively.

Table I10. Subplot (within Cn main plots) values of pH, pH in salt solution, EC (electrical conductivity) and nitrate in the fall sampling. Units are uS cm^{-1} for EC and mg L^{-1} for nitrate.

Treatment	**B Field**			**F Field**		
pH						
	1992	*1993*	*1994*	*1992*	*1993*	*1994*
OF0	6.12 a	6.10	5.88	7.05	7.0	7.0
OF1	5.93 ab		5.83	7.20		7.1
OF2	5.90 ab	6.22	5.88	7.50	7.10	7.1
OF3	5.88 b		6.17	7.25		7.1
NPK	5.53	5.83	5.67	6.50	7.20	6.4
F	(3,6):5.26	(1,2):12.2	(3,6):3.55			
p	0.041	0.073	0.048			
pH_{salt}						
	1992	*1993*	*1994*	*1992*	*1993*	*1994*
OF0	5.75 a	5.30	5.48	6.35	6.25	6.3
OF1	5.67 a		5.63	6.65		6.7
OF2	5.67 a	5.35	5.52	6.90	6.45	6.7
OF3	5.52 b		5.60	6.95		6.8
NPK	5.53	5.15	5.40	6.25	6.35	6.5
F	(3,6):2.78	(1,2):1.00	(3,6):0.43			
p	0.133	0.422	0.737			
EC						
	1992	*1993*	*1994*	*1992*	*1993*	*1994*
OF0	146	101	94.2 a	360	135	133
OF1	161		121 bc	570		165
OF2	171	106	111 ab	650	350	170
OF3	151		141 c	520		105
NPK	147	112	118	375	220	169
F	(3,6):1.27	(1,2):0.43	(3,6):8.13			
p	0.367	0.580	0.003			
Nitrate						
	1992	*1993*	*1994*	*1992*	*1993*	*1994*
OF0	3.0	1.3	5.2 a	3.0	1.3	7.0
OF1	3.67		6.7 a	6.0		6.0
OF2	2.33	1.3	5.8 a	5.0	1.3	8.0
OF3	2.67		16.0 b	5.0		12.0
NPK	10.7	7.3	0.0	12.0	22.0	1.0
F	(3,6):0.12	(1,2):0.00	(3,6):3.85			
p	0.942	1.00	0.038			

Table I11. Soil pH, EC and nitrate on July 16, 1992 and June 11, 1993. Subplot values are averages for Cn, Cp and BW main plots; main plot values are averages for all subplots. Composite samples were analyzed from the B field in 1992. Units are uS cm^{-1} for EC and mg L^{-1} for nitrate.

1992	**B Field**			**F Field**		
Treatment	*pH*	*EC*	*NO3*$^{-}$	*pH*	*EC*	*NO3*$^{-}$
Subplots						
OF0	5.23	237	61	7.08	226	0
OF1	5.15	250	67	7.12	383	3
OF2	5.23	350	167	7.13	486	0
OF3	5.33	193	58	7.16	433	0
NPK	5.70	200	50	6.90	640	10
Main Plots						
Cn	5.16	246	69	7.23	520	3
Cp	5.52	250	34	7.25	500	0
BW	5.02	276	163	6.89	228	0

1993						
Treatment	*pH*	*EC*	*NO3*$^{-}$	*pH*	*EC*	*NO3*$^{-}$
Subplots						
OF0	5.52	136	19	6.56	313	12
OF1	5.58	148	20	6.74	358	8
OF2	5.56	154	16	6.73	372	11
OF3	5.55	161	26	6.70	359	9
NPK[1]	5.32	128	19	6.68	427	12
Main Plots						
Cn	5.51	131	18	6.75	413	9
Cp	5.69	188	23	6.70	366	12
BW	5.46	129	19	6.60	274	9
Statistics						
MP F	(2,4): 1.21 p=0.386	(2,4): 4.78 p=0.087	(2,4): 1.37 p=0.352			
Sp F	(1,6): 0.482 p=0.514	(1,6): 0.208 p=0.664	(1,6): 4.57 p=0.076			
MP*Sp F	(2,6): 0.092 p=0.913	(2,6): 0.551 p=0.603	(2,6) 0.010 p=0.991			

[1] NPK data were not included in the statistical analysis

Table I12. Calculated changes in % soil organic matter and % total N in soil if all of the organic matter and N applied in amendments were recovered in soil samples, and actual changes are compared to Cn (i.e. $\mathrm{SOM}_{\mathrm{treatment}}$ - $\mathrm{SOM}_{\mathrm{control}}$). Assumptions are the same as those footnoted in Table I8.

Treatment	Var.	Incorp. top 15 cm (kg/ha)	B equiv. in soil %	B92 Trt% - Cn%	F equiv. in soil %	F92 Trt% - Cn%
Cp	OM	31450	3.02	1.06	2.49	0.40
				(1.62)[1]		(1.23)[1]
BW	OM	7310	0.70	0.53	0.58	-0.20
NPK	OM	0	0.00	0.46	0.00	-0.30
Cn1	OM	464	0.045	•	0.03	•
Cn2	OM	929	0.09	0.10	0.07	-0.20
Cn3	OM	1393	0.13	•	0.11	•
Cp	N	589	0.057	•	0.047	•
BW	N	470	0.045	•	0.037	•
NPK	N	100	0.010	•	0.008	•
Cn1	N	50	0.005	•	0.004	•
Cn2	N	100	0.010	-0.015	0.008	-0.009
Cn3	N	150	0.014	•	0.012	•

Treatment	Var	Top dr all yrs (kg/ha)	Total Add top 10 cm (kg/ha)	B equiv. in soil %	B94 Trt% - Cn%	F equiv. in soil %	F94 Trt% - Cn%
Cp	OM	0	20967	3.02	0.37	2.50	1.60
					(0.32)[2]		(0.40)[2]
BW	OM	0	4873	0.70	-0.17	0.58	1.10
NPK	OM	0	0	0.00	-0.27	0.00	0.70
Cn1	OM	928	1237	0.18	0.76	0.15	0.60
Cn2	OM	1856	1547	0.22	0.41	0.18	-0.50
Cn3	OM	2786	3715	0.54	0.73	0.44	-0.10
Cp	N	0	393	0.057	0.060	0.047	0.060
BW	N	0	313	.045	0.000	0.037	0.020
NPK	N	300	367	0.053	-0.030	0.044	-0.010
Cn1	N	100	133	0.019	0.007	0.016	0.030
Cn2	N	200	267	0.038	-0.015	0.032	0.007
Cn3	N	300	400	0.058	0.015	0.048	0.003

[1] Value in brackets is the average of differences for (i) Cp and Cn main plots sampled outside of subplot areas (Table I4). (ii) Cp0 and Cn0 subplots, (iii) Cp2 and Cn2 subplots.

[2] Value in brackets is the average of differences for (i) Cp and Cn main plots sampled outside of subplot areas (Table I4). (ii) Cp1 and Cn1 subplots, (iii) Cp1b and Cn1b subplots.

Table I13. Soil biological activity (alkaline phosphatase, respiration, glucose amended respiration, inorganic nitrogen) for main plot and subplot soils sampled in late fall 1994. Units are mg p-nitrophenol kg^{-1} hr^{-1} for P-ase, mg CO_2-C kg^{-1} hr^{-1} for respiration, and mg N kg^{-1} for inorganic nitrogen.

Field & Plots	**P-ase-day 17**	**CO_2-day 7**	**CO_2-glu-day 17**	**CO_2-day 17**	**N-day 17**	**$N_{day\ 17}$-$N_{initial}$**
B FIELD						
Main Plots						
Cn	146	6.09	11.2	11.6	291	40.3
Cp	276*	7.09	17.6*	8.3	310	22.3
BW	134	4.76	12.4	8.6	303	39.3
NPK	79	4.45+	10.4	11.2	258	16.0
Control subplots						
Cn0	133	5.04	11.7	8.1	304	29.0
Cn1	114	4.60	9.9	10.1	284	34.3
Cn2	160	5.01	12.9	8.6	306	55.7
Cn3	137	5.48	9.5	8.5	360	102.3
Cn1bag mow	72	4.60	9.3	7.17	363*	96.0
Cn3 X	171*	6.21	10.3	9.29	332	82.7
Statistics						
Main Plots	F(3,5): 11.56 **p=0.011**	F(3,6): 4.96 **p=0.046**	F(3,6): 5.41 **p=0.038**	F(3,5): 0.99 p=0.470	F(3,6): 1.45 p=0.319	F(3,6): 0.39 p=0.761
Control Subplots (Cn0,1,2,3)	F(3,4): 2.18 p=0.232	F(3,6): 0.93 p=0.482	F(3,6): 1.09 p=0.421	F(3,6): 0.83 p=0.522	F(3,5): 2.34 p=0.190	F(3,5): 1.42 p=0.340
(Cn1 bag mow)	F(1,1): 0.12 p=0.787	F(1,2): 0.00 p=1.00	F(1,2): 0.24 0.674	F(1,2): 2.92 p=0.229	F(1,2): 32.7 **p=0.029**	F(1,2): 6.99 p=0.118
(Cn3X)	F(1,2): 23.72 **p=0.039**	F(1,2): 3.23 p=0.214	F(1,2): 6.21 p=0.130	F(1,2): 0.15 p=0.737	F(1,2): 0.78 p=0.470	F(1,2): 0.26 p=0.663

Table I13. Concluded.

	P-ase-day 17	CO_2-day 7	CO_2-glu-day 17	CO_2-day 17	N-day 17	$N_{day\ 17}$-$N_{initial}$
F FIELD						
Main Plots						
Cn	96	3.30	9.5	8.1	260	198
Cp	200	3.89	10.0	7.6	233	153
BW	166	2.86	10.0	7.2	139	59
NPK	110	2.71	9.0	13.4	160	97
Control Subplots						
Cn0	128	2.27	9.0	9.5	126	63
Cn1	250	4.18	10.5	9.0	205	118
Cn2	174	2.56	10.0	10.0	195	124
Cn3	200	5.50	10.0	7.6	370	298
Cn1bag mow	128	3.30	11.0	11.9	185	115
Cn3 X	94	2.12	8.6	11.0	254	201

Table I14. Respiration, glucose amended respiration and inorganic-N production of fresh soil samples taken Sept 20, 1995 from Cn main plots. Units are mg CO_2-C kg^{-1} hr^{-1} for respiration and mg N kg^{-1} for nitrate. N incr refers to the increase in total inorganic N over 7 days.

Block	**Respiration**		**Nitrate**		**Ammonium**		**N incr**
	-glu	+glu	init	7 day	init	7day	
1	2.2	8.1	1.7	5.4	4	85	84
2	1.9	6.6	1.5	8.7	17	145	135
3	2.4	7.7	1.0	7.2	43	181	144
1-3 avg	2.2	7.5	1.4	7.1	22	137	121
4	1.5	4.4	1.4	5.0	31	68	41

Table I15. Mean values for soil variables in mulch mowed and bag mowed plots for Cn (OF1 level), Cp (OF1 level), and NPK main plots in fall, 1994.

	OM (%)	**P (ppm)**	**K (ppm)**	**Mg (ppm)**	**Ca (ppm)**
B field					
mulch	4.67	72	101	190	1156
bag	4.53	62	85	170	1062
F field					
mulch	3.20+	178	167	104	1594
bag	2.23	169	180	89	1522
B field stats					
MP (2,4): p	0.627	0.014	0.0003	0.014	0.045
Sp (1,6): p	0.865	0.251	0.953	0.197	0.794
MP*Sp (2,6): p	0.492	0.394	0.801	0.246	0.168
cv MP	15.2	31.7	15.3	12.8	26.4
cv Sp, MP*Sp	14.4	32.3	36.9	12.0	10.4
F field stats					
Sp (1,2): p	0.057	0.812	0.569	0.480	0.500
cv Sp	10.8	24.4	14.3	22.7	6.9

	pH cl[1]	**pH fr[2]**	**pHsalt**	**EC (uS cm^{-1})**	**NO3 (mg L^{-1})**
B field					
mulch	6.38	5.74	5.55	120+	4.22
bag	6.35	5.87	5.51	95	4.11
F field					
mulch	7.07	6.57	6.47	156	2.67
bag	7.13	6.57	6.10	131	1.33
B field stats					
MP (2,4): p	0.149	0.752	0.432	0.148	0.198
Sp (1,6): p	0.569	0.337	0.627	0.086	0.939
MP*Sp (2,6): p	0.105	0.178	0.194	0.209	0.498
cv MP	4.2	6.3	5.2	19.5	136
cv Sp, MP*Sp	1.2	4.3	3.3	23.4	71.2
F field stats					
Sp (1,2): p	0.773	1.00	0.380	0.424	0.057
cv Sp	3.5	3.2	6.4	2.2	20.4

[1] cl = commercial lab

[2] fr = frozen soil sample

Table I16. Mean values for soil variables in OF3 and OF3X (no fertilizer in 1994) plots in Cn and BW main plots, fall 1994. There were no significant MP*Sp interactions for the B field (n=6, 2 for B and F fields respectively).

	OM (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)
B field					
3	4.97	33	66	237	1169
3X	5.08	36	69	230	1111
Sp p	0.390	0.731	0.620	0.687	0.375
F field					
3	2.85	112	157	87	1560
3X	3.10	94	140	104	1658

	pH cl	pH fr	pHsalt	EC (us cm^{-1})	NO3 (mg L^{-1})
B field					
3	6.32	5.87	5.58	130	9
3X	6.22	5.83	5.57	132	9
Sp p	0.305	0.867	0.866	0.901	0.971
F field					
3	7.15	6.70	6.15	131	6
3X	7.25	7.00	6.60	162	6

J. Leaf/soil nutrient relationships

Soil nutrient values indicate the size of particular reserves of the various nutrients in the horizons sampled. Ratings are assigned to these values by soil testing labs to indicate adequacy for the crop in question, the usual criteria being to assign these as follows:

> "low" ratings for soil values when crops nearly always respond to fertilizer;
>
> "medium" ratings when crops frequently respond to fertilizer;
>
> "high" ratings when crops rarely respond to fertilizer.

Fertilizers are commonly applied in amounts sufficient to bring soil values up to a high rating, plus an amount equal to the estimated removal and loss between fertilization intervals (Lanyon, 1992) , thus,

> *kg fertilizer nutrient/ha* = (kg/ha in soil at high rating - kg/ha in soil at current rating) + kg/ha removed by crop + kg/ha lost by leaching, immobilization etc.

Amounts removed by the crop are estimated from data for particular crops. Amounts removed by other processes are related to the crop type, soil type, climate and management, but can usually be estimated. The weakest feature is usually assignment of the rating itself, which varies with crop type and site specific factors. Large differences have been found between recommendations for fertilizer amendments given by different soil testing labs when they have analyzed the same soil samples (Donald and Warman, 1992; DeVault, 1982 a,b,c; Turner and Waddington, 1978). In theory, soil tests should be calibrated for specific crops, soils and management. In practice, values are extrapolated to a wide range of conditions, with a bias towards overestimating actual requirements in order to ensure that crops are not under fertilized. Differences in the degree of this bias are one of the reasons for variability between soil labs in their recommendations for fertilizer. This generally means that when calibrations of ratings are made for particular situations, the likelihood is that the ratings will be shifted downwards in relation to soil values, i.e. the limits for adequacy of nutrients will be lowered.

Very little soil-crop calibration work has been conducted in Nova Scotia (Donald and Warman, 1992), and probably none for turf. Turner and Hummel (1992) considered turf grass soil test calibration studies to be one of three priorities amongst turf grass fertility research needs. (Others were micronutrient studies and nutrient interactions).

The leaf nutrient data obtained at The Oaks give a good indication of adequacy of supply of N, P, K, Mg and Ca. Hence we examined the soil and plant data post-hoc to determine how predictive soil data might have been of the leaf P, K, Mg and Ca and by implication, of possible nutrient limitation of turf quality (except for N).

Methods

It is generally recommended that soil sampling be conducted in late fall or early spring. Thus we examined the relationships of leaf P, K, Ca, and Mg in turf grass, sampled in mid-summer (data from Section III.1G) to soil P, K, Ca, and Mg values for samples taken in the previous fall (data from Section III.1I).

There are three separate data sets:

(i) Soil samples taken October, 1992; leaf samples taken July 13, 1993.
(ii) Soil samples taken October 1993; leaf samples taken Aug. 11, 1994.
(iii) Soil samples taken late October, 1994; leaf samples taken Sept. 2, 1995.

Set (iii) leaf samples were those taken to examine leaf P of a few selected plots in Block 3, where exceptional low soil P values had been recorded for samples taken in the fall of 1994. For comparison, leaf samples were taken from Cn0 plots in each of the other blocks.

Data sets were examined for significant monotonic relationships using a non-parametric test (Spearmans Rank Correlation); where that test was significant, the data set was further examined for linear and quadratic (saturation type) responses of leaf nutrients to soil nutrients.

Results

Phosphorus

- Mehlich III P values of soil samples from The Oaks, varied from close to zero (2 ppm) to 445 ppm which is almost 10 fold the upper limit for high (H) ratings assigned by the commercial lab (Table J1).

- There was a highly significant positive linear relationship between leaf P and soil P for the leaf94/soil93 data set (Table J2), which indicates that the turf grass was responding to the P pool measured in the Mehlich test.

- Block 3 soil samples had some exceptionally low P values (< 5 ppm) in 1994. Nevertheless, the corresponding leaf P values were above the OMAF critical value (0.15%), and only one was slightly below the Jones (1980) critical value of 0.30% (Fig. J1).

- Regressions of leaf P on soil P for the leaf94/soil93 data set (which has a high R^2 value) and the leaf95/soil94 data set (which included P values close to zero) have Y intercepts of 0.33%P and 0.37%P respectively (Fig. J2).

Thus, both the regression data and the actual leaf values at low soil P suggest that even with exceptionally low Mehlich III P in the soil, the turf grass would still have approximately 0.35% P, and would not be P limited. This suggests that the turf had access to a pool of P that was not measured by the Mehlich III test, and that this pool was sufficient to meet requirements.

- Only three of the 56 data points had leaf P values above 0.55%, the upper limit for P given by both OMAF and Jones (1980). The corresponding soil values were all over 150 ppm P; there were eight data pairs in which soil P was greater than 150 ppm, and leaf P% was less than 0.55%P (Fig. J1).

It appears then that the Mehlich III test is measuring a biologically meaningful pool of P, but for this particular system, the turf had access to other pools or was able to make more efficient use of that pool than is the case in some other turf systems. There was very little evidence for excessive levels of P in the turf, even though more than half of the soil samples had P in the very high (VH) category (>50 ppm P).

Potassium

- Potassium levels, in The Oaks soil samples, like those for P varied over a large range (26-545 ppm) with ratings covering the entire span of VL to VH (Table J1).

- As was the case for P, none of the leaf samples had K values below the OMAF critical level of 0.9% or the Jones (1980) level of 1% (Fig. J1). Nor were there any over the OMAF maximum (4%), however, a few were over the Jones (1980) maximum (2.5%).

- A significant correlation was observed for the leaf93/soil92 data, and was better described by a quadratic (saturation type), than by a linear function (Table J2). A regression of leaf %K on soil K (ppm measure) for data pairs in which soil K was <100 ppm gives extrapolated values of 32.6 and 38.9 ppm K for leaf %K values of 0.9 and 1.0 respectively (Fig. J2)

The commercial lab's ratings (Table J1) would have the upper limit for the low (L) category at approximately 110 ppm, and for the very low (VL) category, at approximately 79 ppm (only approximate designations can be given because the ratings depended also on the % of CEC occupied by K). Hence, as in the case of P, the ratings appeared to overestimate quite considerably, the need for K supplements.

Magnesium

- The commercial labs rating system for magnesium was apparently based mostly on the % CEC occupied by Mg. Soil sampled from The Oaks fell in the low (L), medium (M) and high (H) categories (Table J1).

- One leaf %Mg value fell below the OMAF critical minimum (0.13%), and seven were below the Jones (1980) limit of 0.17% (Fig. J1).

- There was a significant linear regression for the leaf94/soil93 data which was not improved by a quadratic expression. Extrapolation of that regression line indicates soil magnesium values of 4.8% and 3.0% at leaf Mg values of 0.15% and 0.13% respectively (Fig. J2). Five percent of CEC is a commonly cited suggested minimum for Mg (Karlen and Sharpley, 1994) which appears to be supported by our data.

The commercial lab's lower limit for the low (L) category was apparently 5%. Five of the six leaf values that were below 0.15 %Mg, were from soils with %Mg in the 5-9.9% interval. Hence in this case, the commercial lab's rating system for soil Mg identified an interval in which low leaf Mg was actually observed.

Calcium

- The commercial labs rating system for calcium was apparently based mostly on the % CEC occupied by Ca. Soil values at The Oaks varied widely (15.2 to 88.9%) and ratings covered the entire span of VL to VH (Table J1).

- None of the leaf Ca values were below the OMAF critical value (0.2%), however, 14 of 75 values in the data sets were less than the Jones (1980) critical value (0.5%), none were below 0.4%.

These data suggest that the grass at The Oaks was not Ca limited even though more than half of the soil values were in the VL category.

- There was a significant positive linear relationship between leaf Ca and soil Ca (% of CEC) for the leaf94/soil93 data. Extrapolation of that regression line indicates a soil Ca value of 6.25% at a leaf Ca value of 0.5%.

Discussion

The significant correlations between leaf nutrient values and soil nutrient values provide some evidence that the sampling and analytical procedures used for soils were reliable. Overall, the data suggest that higher ratings could be assigned for the soil P, K, and Ca values at The Oaks than those given by the commercial lab, while there was fairly good agreement in regard to Mg (we would expect Mg limitation to be expressed in most cases where soil Mg drops below 5% of soil CEC). The commercial lab's rating system is probably fairly typical and probably even on the conservative side as it takes some account of cation exchange characteristics which many labs do not. It is unlikely that other labs would have given significantly higher ratings for these samples. Thus the higher ratings we would assign represent a site and management specific refinement of the commercial lab ratings, which is in the direction predicted, i.e. site and management specific data suggest lower requirements for nutrients than those given by a system which is applied to a wide range of sites and management.

We emphasize also, that we were making use of the *available data* to evaluate adequacy predictions as best we could from the soil data, and the experiments were not set up to specifically examine this question. There are many questions that remain unanswered, such as;

(1) Were leaf nutrient values in fact reliable indicators of possible limitation of turf quality?

(2) How did the different species of grass respond to the nutrients?

(3) Could there have been limitations at other times of the year?

(4) How do the ratings apply to clover?

The paucity of information on such questions - and the expense of obtaining it - behooves us to make the best use of available data, but at the same time to be cautious in the interpretation or in extrapolation of conclusions to other systems.

The apparent adequacy of grass P nutrition even at close to zero Mehlich III P values is particularly interesting, given interest in reducing P applications in order to minimize runoff of P into surface waters. The grass was responding to the P pool represented in the Mehlich III extraction, however it is evident that there was another pool available to the grass, or that the grass was able to extract P at much lower levels of P than is usually the case. Some possibilities are soil organic P or perhaps enhanced mycorrhizal uptake of P at low soil P levels. It would obviously be appropriate to find an explanation for these results and whether they are they associated with specific management practices such as mulch mowing. In any case, the results suggest that if local turf soils test low for P, it might be appropriate to conduct leaf analyses to determine whether P is actually limiting.

Table J1. Commercial lab's ratings for The Oaks soil samples. For the cations, the lab reported values in ppm units and as percentages of the cation exchange capacity. Both variables are used by the lab in assigning ratings. There was no overlap in ratings for reported %CEC values for Mg and Ca, but there was overlap for ratings assigned to ppm values (i.e. a given ppm value could have had a higher or a lower rating according to the %CEC value). For potassium, there was overlap in relation to both sets of values but the overlap was less for the ppm values than for the %CEC values; the italicized values are the intervals in which there is overlap in the assignment of ratings to the K ppm values. Data are from 154 soil samples.

Soil Nutrient	**VL**	**L**	**M**	**H**	**VH**
P: ppm	2-9	10-19	20-29	30-49	>50-445
Mg: %CEC		5.3-9.9	10-14.9	15.0-22.7	
ppm		59-211	108-256	209-320	
Ca: %CEC	15.2-44.4	45.2-54.9	55.5-74.9	75.3-82.3	85.5-88.9
ppm	467-1442	973-1810	1158-1910	1358-2062	1416-1661

Soil Nutrient	**VL**	*VL/L*	**L**	**M**	*M/H*
K: ppm	26-73	*79-82*	84-110	111-140	*143-148*
%CEC	0.5-1.8	*1.1-1.8*	1.5-3.0	2.4-3.9	*2.7-4.5*

	H	*H/VH*	**VH**
K: ppm	153-216	*221-227*	233-545
%CEC	2.8-5.9	*3.8-5*	4.2-10.2

Table J2. Statistics for rank correlations, linear and quadratic regressions of leaf nutrients on soil nutrients. Linear regression data are given when Spearman Rank Correlation is significant; quadratic regression data are given only when quadratic term improves the regression ($\alpha = 0.05$).

Variable + Data Set		Rank Correlation			Linear		Quadratic	
		n	rho	P	R^2	P	R^2	P
Leaf P vs Soil P								
1993	1992	28	0.159	0.397				
1994	1993	19	0.711	0.003**	0.535	0.0004**	Not improved	
1995	1994	9	0.254	0.500				
Leaf K vs Soil K								
1993	1992	28	0.614	0.001**	0.324	0.002**	0.448	0.001**
1994	1993	19	0.083	0.738				
1995	1994	9	0.154	0.671				
Leaf K vs Soil %K								
1993	1992	28	0.552	0.004**	0.171	0.029*	0.332	0.006**
1994	1993	19	0.064	0.803				
1995	1994	9	0.137	0.705				
Leaf Mg vs Soil Mg								
1993	1992	28	0.364	0.060+	0.042	0.295	0.186	0.076+
1994	1993	19	0.579	0.015*	0.366	0.006**	Not sat'n[1]	
1995	1994	9	0.100	0.777				
Leaf Mg vs Soil %Mg								
1993	1992	28	0.026	0.881				
1994	1993	19	0.596	0.012*	0.346	0.008**	Not sat'n	
1995	1994	9	0.167	0.637				
Leaf Ca vs Soil Ca								
1993	1992	28	0.284	0.142				
1994	1993	19	0.636	0.007**	0.382	0.005**	Not improved	
1995	1994	9	0.404	0.253				
Leaf Ca vs Soil %Ca								
1993	1992	28	0.285	0.140				
1994	1993	19	0.738	0.002**	0.559	0.0002**	Not improved	
1995	1994	9	0.387	0.276				
Leaf Mg vs Soil Ca/Mg								
1993	1992	28	0.752	0.0001**	0.438	0.0001**	Not sat'n	
1994	1993	19	0.599	0.009**	0.406	0.003**	Not sat'n	
1995	1994	9	0.167	0.637				

[1] "not sat'n" means that the quadratic relationship is not a saturation type response.

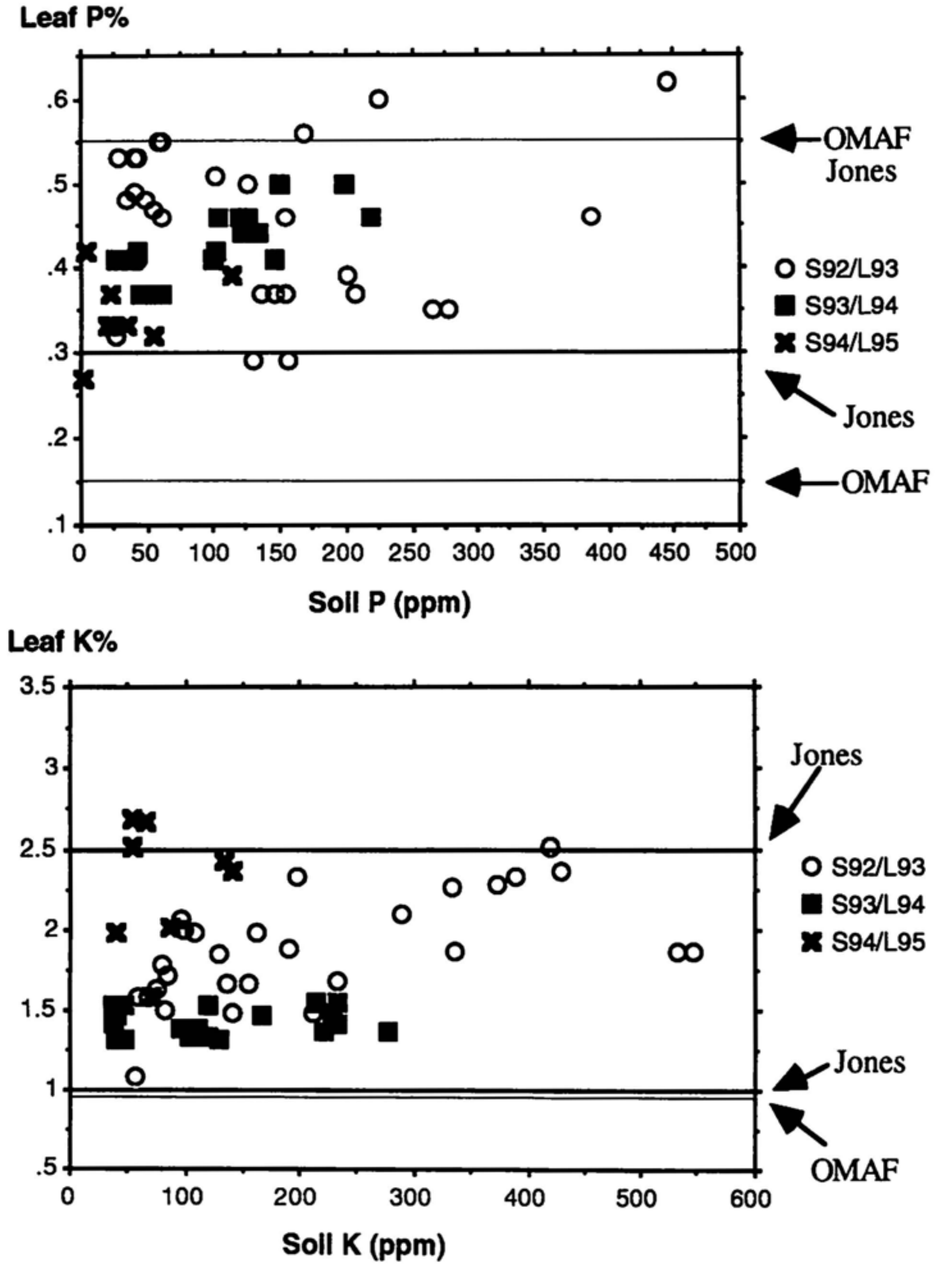
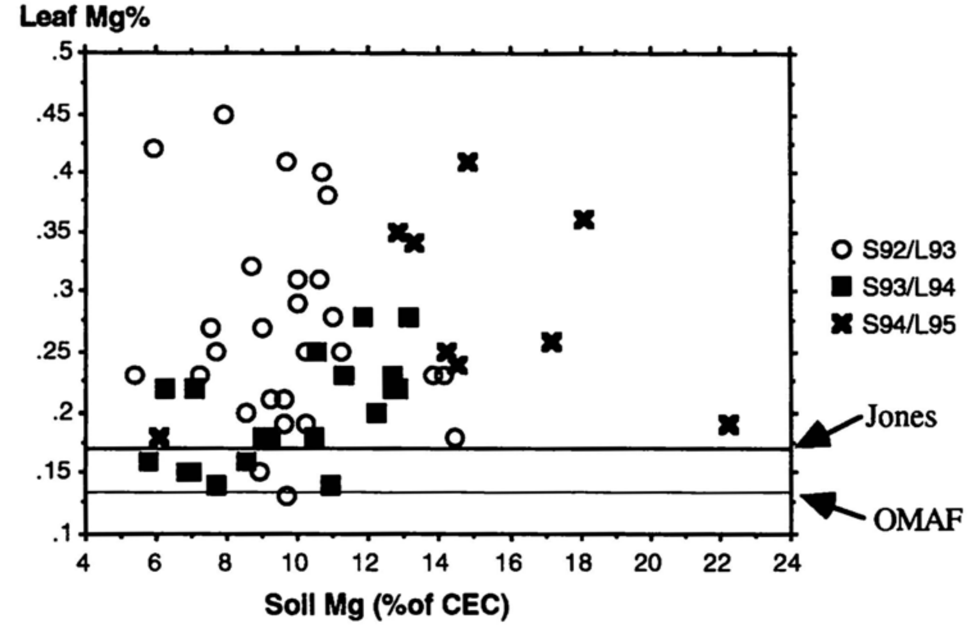


Figure J1. Plots of leaf nutrients vs soil nutrients for three data sets. Arrows indicate the sufficiency levels for individual nutrients in turfgrass as given by OMAF (1992) and Jones (1980); seeTable G1.



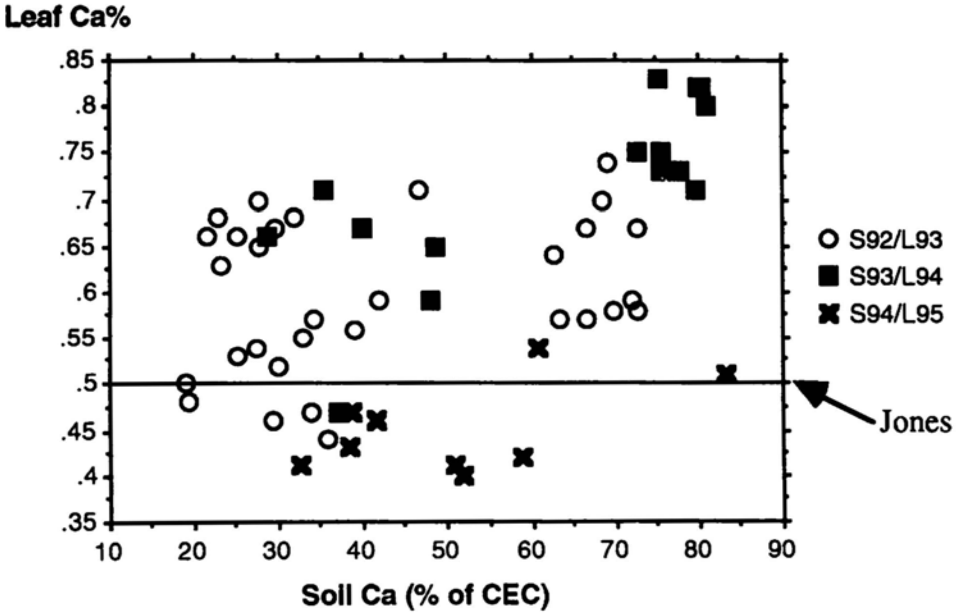


Figure J1. Concluded.

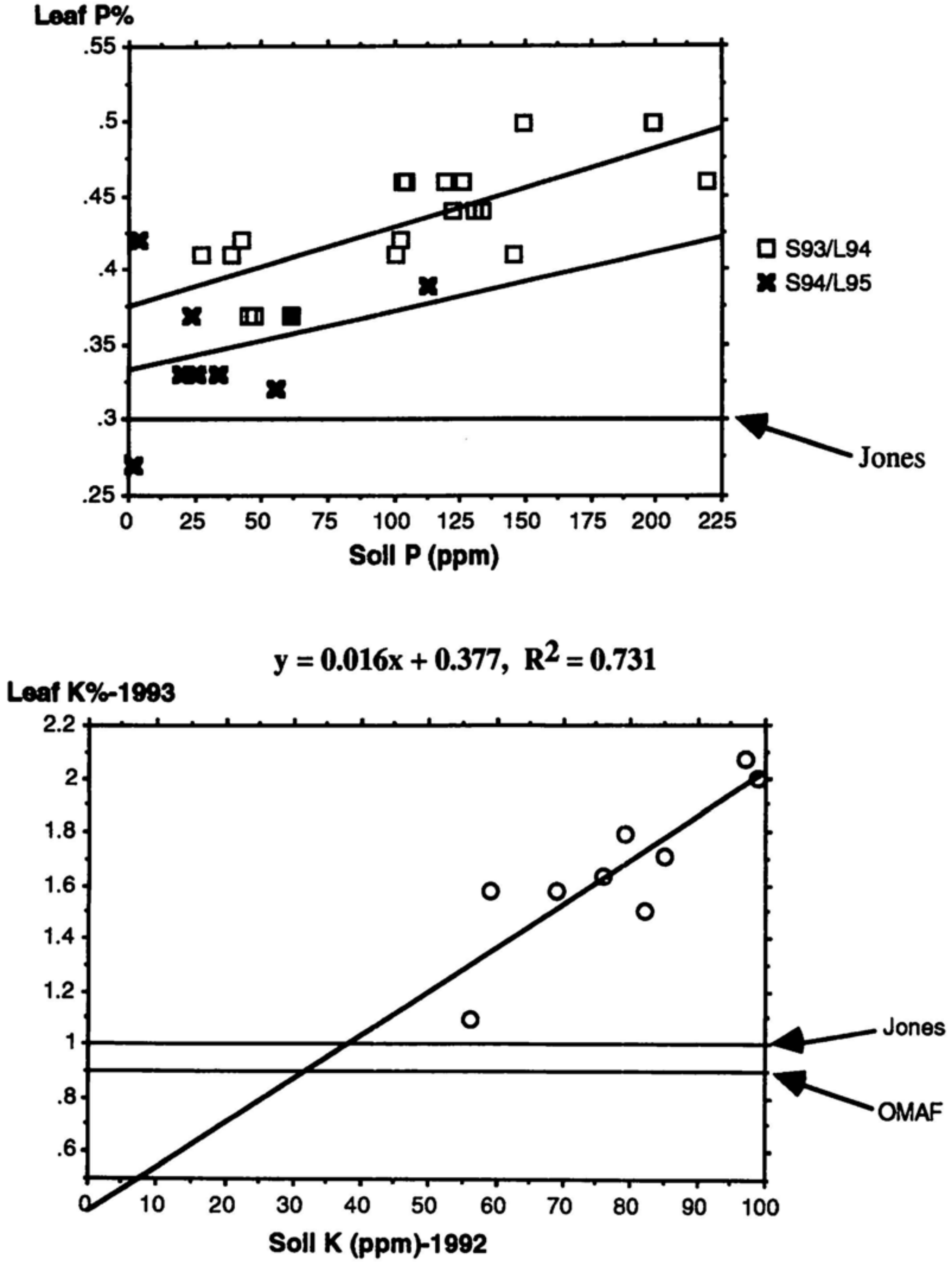
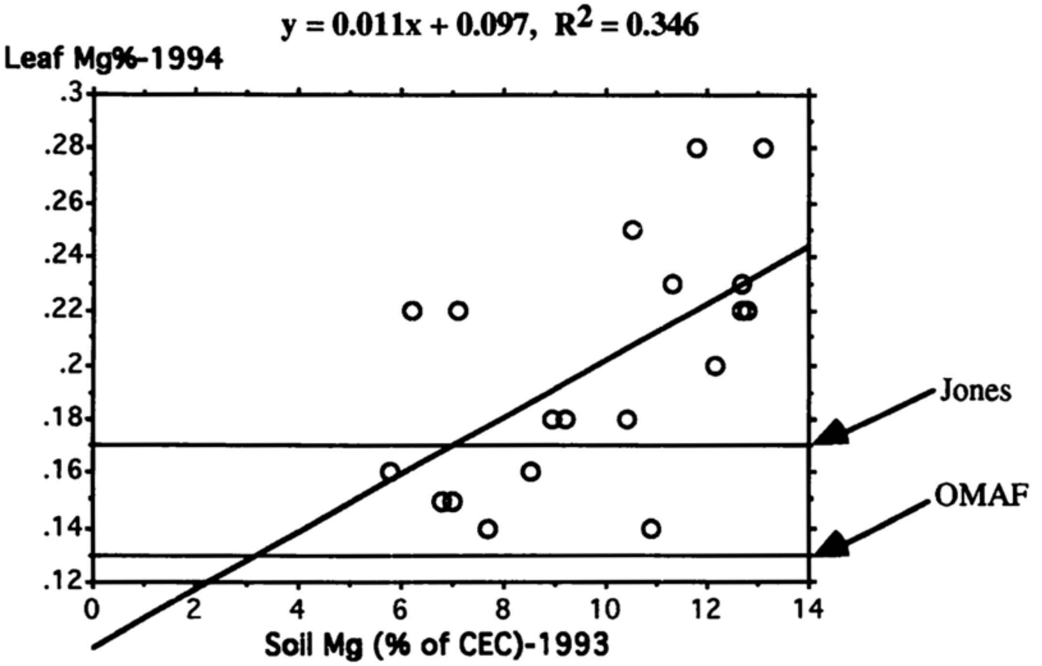


Figure J2. Regressions of nutrient levels in leaves (%) against soil levels (ppm or % of CEC) in the previous season.



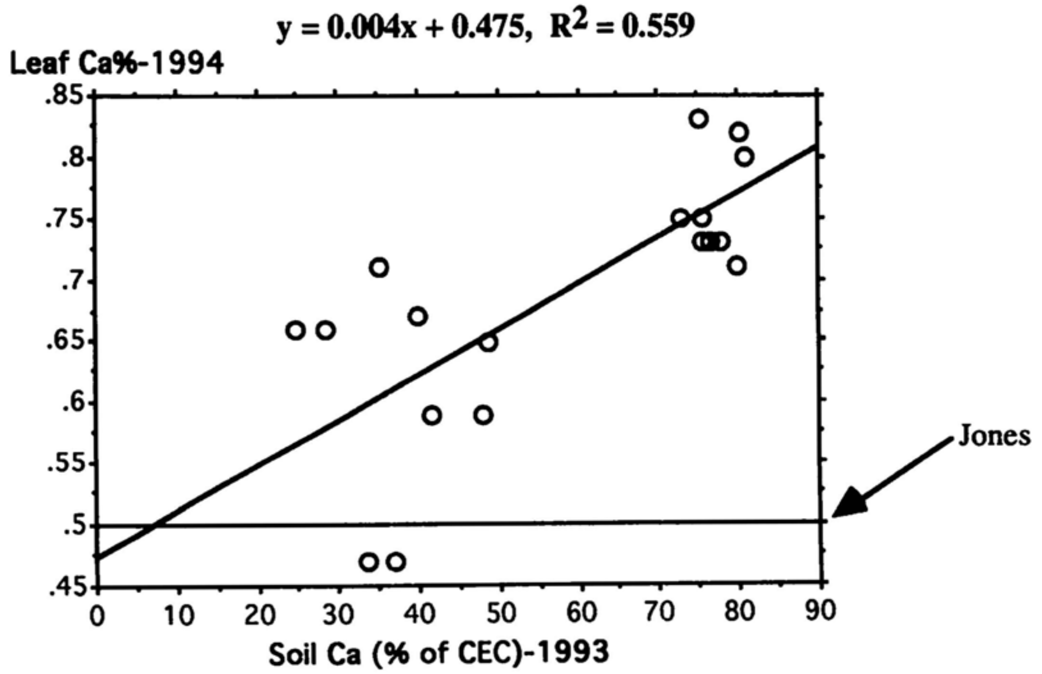


Figure J2. Concluded.

III.2 THE MIXTURES EXPERIMENTS

The principal experiment consisted of a comparison of three mixes (tall fescues, Ecomix and Greenfast) in main plots that were seeded with or without clover. The mixes were sown on plots that had received compost as in the Cp main plots in the Fertility Experiments. Minus clover plots received organofertilizer at 3 lbs N per annum as in the fertility plots, while mixes sown with clover did not receive any organofertilizer. Thus the experiments had a split plot design with plus and minus clover being the main plot variable, and the different mixtures, the subplot variable (as summarized below).

Main plot minus clover	Main plot plus clover
-Compost incorporated	-Compost incorporated
-Organofertilizer supplied at 3 lbs N per annum	-No other fertilizer applied
Subplots	Subplots
Tall fescues (no clover)	Tall fescues (with clover)
Greenfast (no clover)	Greenfast (with clover)
Ecomix (no clover)	Ecomix (with clover)

There were three replicates, i.e. three blocks each with one main plot minus clover, and one main plot plus clover. The plus and minus main plots were physically separated (Fig. II.2) Two blocks were located on the B field and one on the F field. Unlike the situation for the fertility experiments, there was no indication that main plot, subplot and main plot x subplot effects differed sharply in direction or intensity between the B and F fields, so the data were treated as a single data set.

We also established subplots of a blend of Kentucky bluegrasses on the NPK main plots on the B field. This enabled comparison of Kentucky bluegrass with Ecomix on plots receiving NPK fertilizer. The design was a randomized complete block design with three replicates (subplots were set up on the B field NPK main plots only).

Except where stated, observations were made within each of three quadrats placed at random within each plot. The precise methodology for observations followed that described in Section III.1.

Results

Greenness

Greenness of subplots within each main plot was ranked. Chlorophyll readings were used to compare greenness between minus and plus clover main plots.

- By the summer of the establishment year (1992), Ecomix was noticeably greener than the other mixes. By fall, the tall fescues had darkened in comparison to Ecomix, and through most of the summer and fall in 1993 and 1994, the tall fescue plots were clearly the darkest green (Fig. III.2.1, Photo 15b). However, much of the grass in the tall fescue plots bleached in the late fall of 1993 and 1994 (Photo 6c), and did not green up in the following spring (1994) until late May.

- Trends between mixtures were similar in the plus and minus clover main plots. Chlorophyll readings did not indicate large differences in greenness between plus and minus clover plots (Fig. III.2.2). The chlorophyll readings (Fig. III.2.2, Table III.2.1) were apparently insensitive to the marked differences in the hue of greenness between tall fescues and the other mixes noted visually (Fig. III.2.1), and by film (Photo 15).

- There were not consistent differences in ranking of Ecomix and Kentucky bluegrass on the NPK main plots (Fig. III.2.1).

- During the height of the droughty period in early September of 1995, individual blades of Kentucky bluegrass in Ecomix on the B field were consistently observed to be lighter green than blades of perennial ryegrass (the field as a whole did not exhibit mid-summer drought induced dormancy, in contrast to many residential turfs in the vicinity).

Winter injury

- As in the fertility experiments, there was extensive winter injury on the mixture plots in 1992/1993. It was significantly greater in the plus clover plots than in the minus clover plots (Fig. III.2.2, Table III.2.1).

In the fertility experiments, winter injury was reduced by organofertilizer (Section III.1D), thus we attribute the differences between plus and minus clover main plots in this experiment to the addition of organofertilizer to the minus clover plots.

- Winter injury was lowest on the Kentucky bluegrass plots (Fig. III.2.2).

- Winter injury appeared severe in all tall fescue plots in April and May 1993 (Photo 3), but only the Block 1 and 2 plus clover tall fescue plots suffered a very large long term reduction in the tall fescues (see under species below). The injury pattern was patchy, leaving large holes which were filled mostly by clover growing up from the old seedbank in the minus clover plots.

- In 1993/94, only the tall fescues exhibited a lot of winter injury, or what appeared to be winter injury (Fig. III.2.2). The grass was bleached and heavily infested with pink snow mold (Fig. III.2.2, Photo 14b) In spite of that, however, the plots that had retained good stands of tall fescue in the summer of 1993 (all of the minus clover, tall fescue plots, and tall fescue plus clover in Block 3), appeared to recover fully by mid-June of 1994.

<u>Diseases</u>

- Red thread occurred in the mixes, (Fig. III.2.2) but at relatively low frequency compared to many of the fertility plots at the same times (Section III.1F).

- In 1993, red thread was insignificant on the minus clover plots, but was present on the plus clover plots, which we attribute to application of organofertilizer to the former. In 1994, generally higher levels were observed, which we attribute to overall buildup of innoculum at The Oaks (Section III.1F).

A curious difference occurred between the Ecomix and Kentucky bluegrass subplots on the NPK main plots. Although in 1993, we observed red thread almost exclusively on Kentucky bluegrass within the Ecomix, it was much less abundant in the monoculture Kentucky bluegrass subplots, than in the Ecomix subplots in which Kentucky bluegrasses accounted for only about (20%) of the grasses. Close inspection revealed that within the Kentucky bluegrass plots, red thread occurred only in areas where there was no clover. Thus we attribute the reduced red thread in the Kentucky bluegrass to the higher amount of clover in these plots (see below). Another factor could be that the Ecomix included only one cultivar of bluegrass (Haga), while the blend contained 50% Haga and 50% Gnome.

- Anthracnose occurred in the mixture plots, as it did in the fertility plots, but we did not make detailed observations on it. On the F field, it was noticeably abundant in the minus clover Greenfast plots; these plots appeared to be slightly water stressed in 1994.

- Pink snow mold was prolific in the tall fescue plots in the spring of 1994 (Fig III.2.2; photo 14b) and 1995 (informal observation).

Species

Clover frequency data are presented in Figure III.2.3 and visual estimates of percent cover for clover and other species in Table III.2.2.

- On the B field, clover established from the old seedbank in the minus clover plots, and invaded the F field minus clover plots as on the rest of the fertility plots (Section III.1C). In August 1992, the frequency of clover in Ecomix plots (minus clover) was significantly less than that in tall fescue and Greenfast plots. Clover frequency in Ecomix was numerically the lowest on August 6, 1993 and on April 28, 1994, but on July 11, 1994, the frequency values were similar for all mixtures (minus clover). Visual estimates of clover abundance show similar trends (Table III.2.2) to the frequency data except that tall fescue consistently had the highest clover abundance. We attribute that to clover invading space repeatedly opened by winter injury.

- In all sets of frequency and visual percent cover observations, clover was more abundant in the Kentucky bluegrass subplots than in the Ecomix on NPK main plots. The differences were not statistically significant for individual observation sets, but collectively they were (by the binomial theorem, p= 1/128 = 0.008; this is for the four sets of observations in Fig III.2.3, two sets in Table III.2.2, and an additional set of observations on July 4, 1993 in which visually estimated clover cover averaged 15.5% in Ecomix and 37.6% for Kentucky bluegrass).

- Bentgrass invaded all Kentucky bluegrass plots on the B field forming distinct clumps (Photo 9e). There were no clumps in NPK-Ecomix treatments except on the F field, and none in other treatments.

Pure stands of Kentucky bluegrass are well known to be susceptible to invasion by bentgrass species. Kentucky bluegrass is more susceptible at low pH, and encroachment by bentgrass can be reduced by maintaining a pH of circa 6.5 (Watschke and Schmidt, 1992).

- Clover frequency and percent cover declined in the plus clover plots between 1993 and 1994 (Fig. III.2.3, Table III.2.2), while values for minus clover increased (frequency) or changed only slightly. All plus clover plots and minus clover plots in Blocks 2 and 3 received significant shade for part of the day.

- Perennial ryegrass abundance in Ecomix and Greenfast mixes decreased relative to Kentucky bluegrass between 1993 and 1995 (Table III.2.2), as was the case for Ecomix in the fertility experiments (Section III.1C). Both Kentucky bluegrass and perennial ryegrass invaded tall fescue plots, but there was very little invasion in the reverse direction (Table III.2.2).

- The first winter resulted in a lot of winter injury to tall fescue, which was more severe overall in the plus clover than in the minus clover plots. After that, the percent cover by tall fescue in tall fescue plots remained more or less the same on the plus clover plots, while in the minus clover plots it increased in Block 1 (which had the lowest percent in 1993) but decreased in Blocks 2 and 3, converging on values of 70-80% (Table III.2.3).

Biomass (verdure)

- Verdure was measured in mid-July of 1993 and 1994 (Fig III.2.4). There were not large variations in verdure between mixtures. Verdure was significantly lower in the plus clover main plot; this difference was larger in 1993 than in 1994. We attribute the difference in 1993 to application of organofertilizer on the minus clover plots, and the lessening of differences in 1994 to enhanced turnover of compost nutrients.

- Measurements of verdure were made in minus clover and plus clover patches within the plus clover plots in 1993, and in both plus and minus clover plots in 1994. The 1993 data show a positive effect of clover on biomass, and the 1994 data, a fairly strong negative effect.

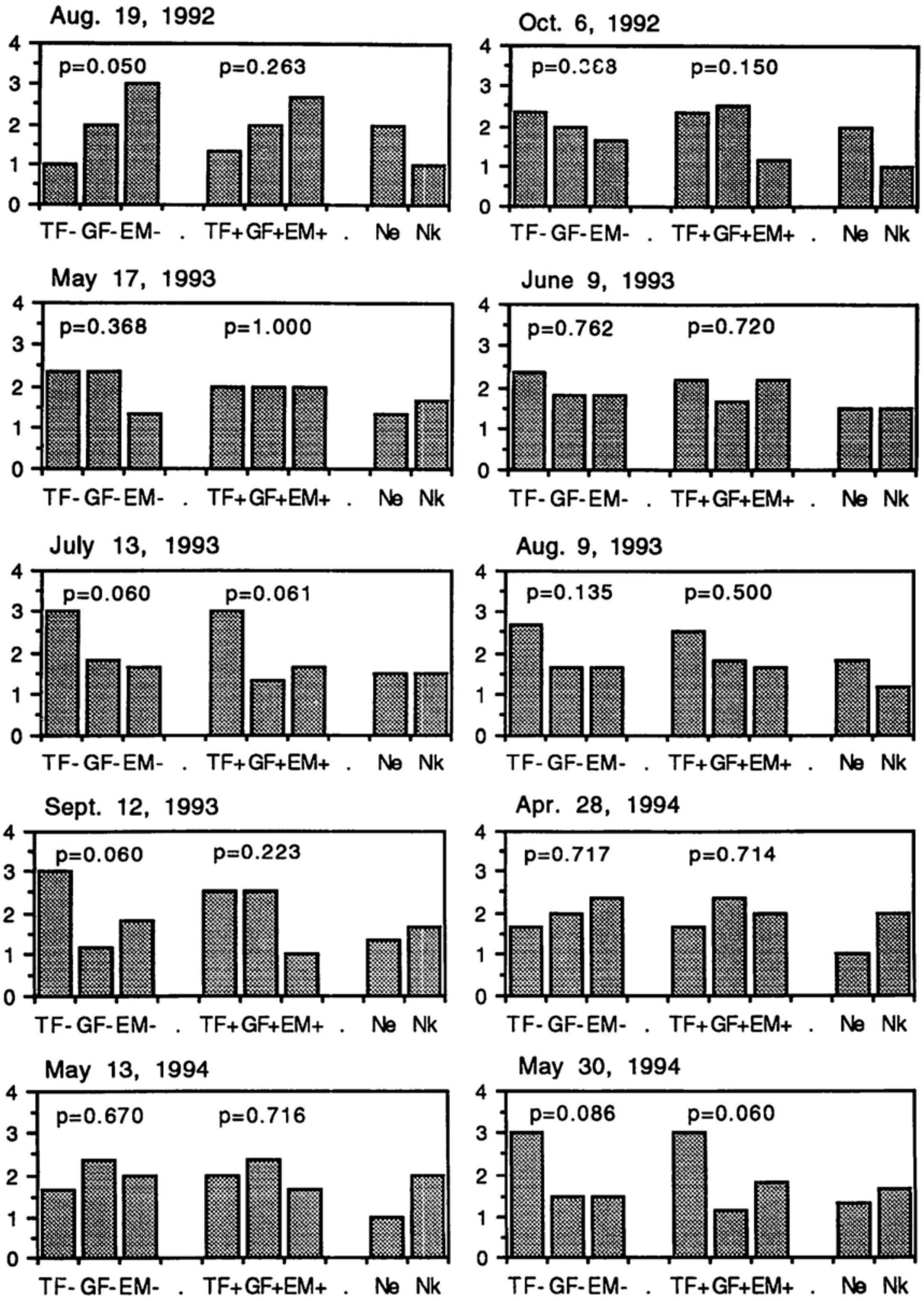


Figure III.2.1. Visual greenness ranking for mixture plots and NPK-Ecomix, NPK-Ktb plots.

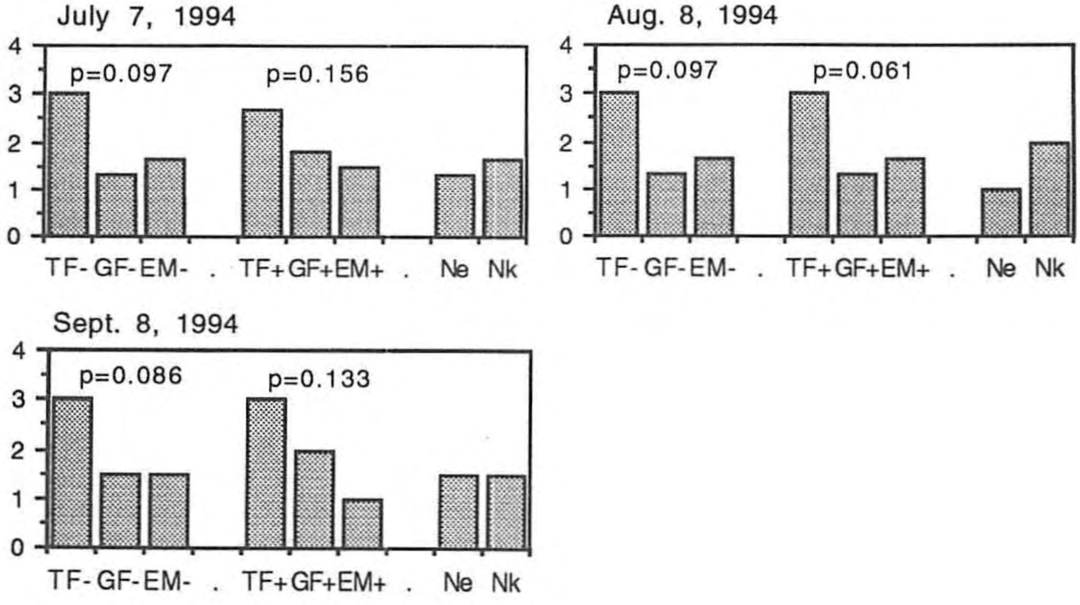
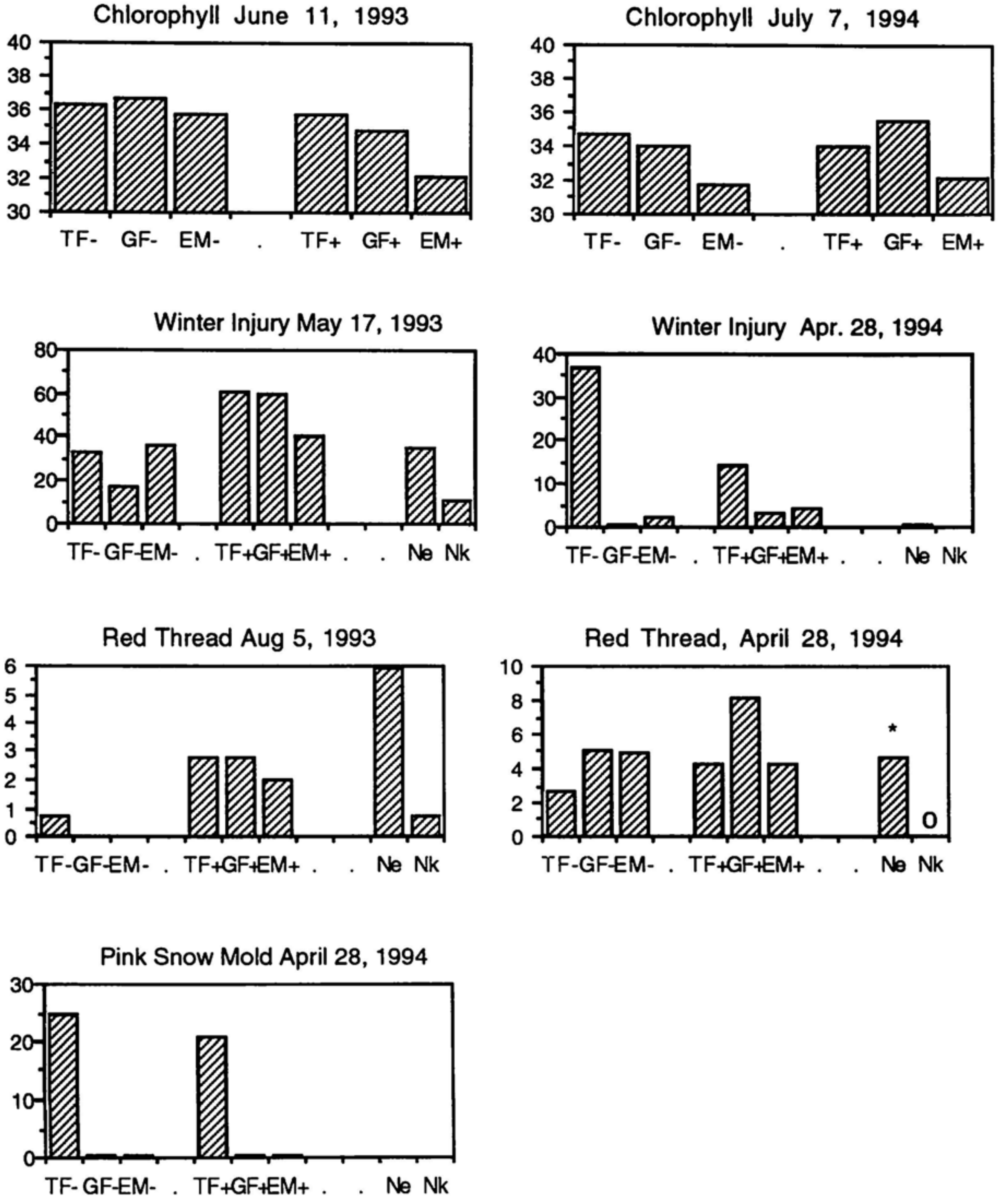


Figure III.2.1. Concluded.



Chlorophyll June 11, 1993

Chlorophyll July 7, 1994

Winter Injury May 17, 1993

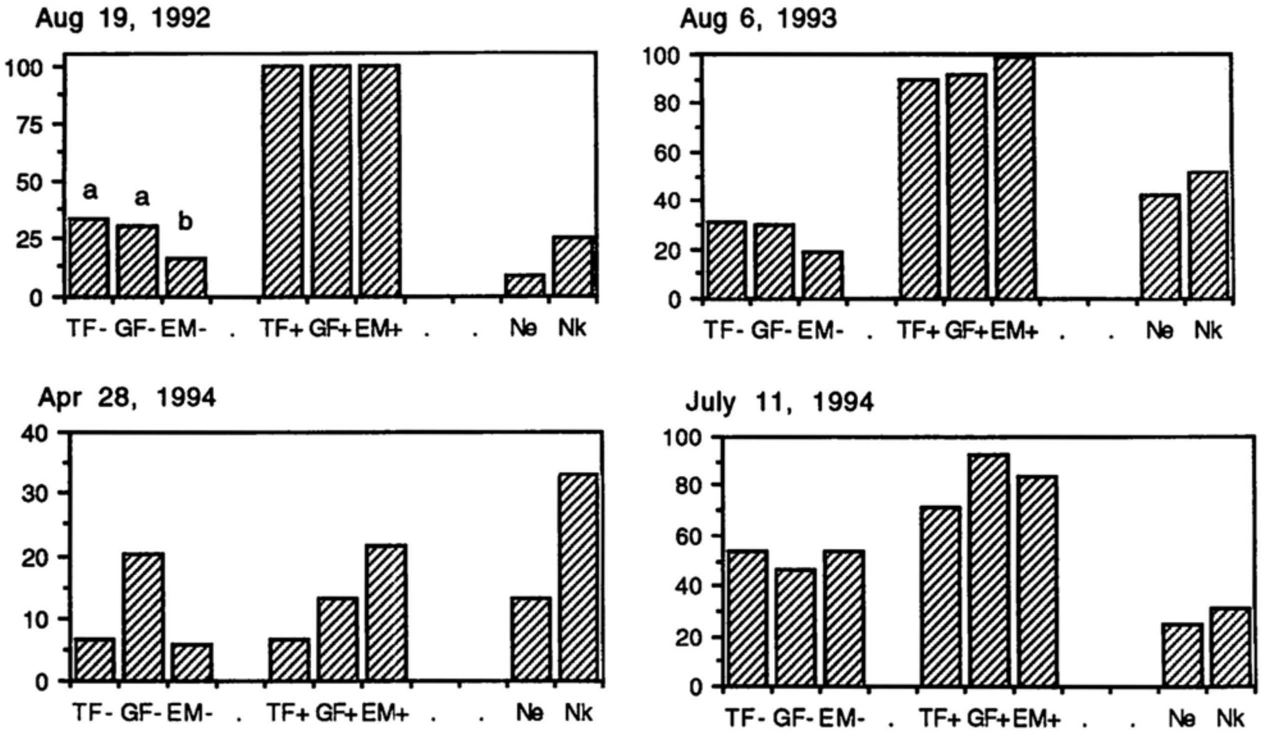
Winter Injury Apr. 28, 1994

Red Thread Aug 5, 1993

Red Thread, April 28, 1994

Pink Snow Mold April 28, 1994

Figure III.2.2. Chlorophyll, winter injury, red thread and pink snow mold in mixture plots. Units are SPAD units for chlorophyll, percent cover for winter injury, red thread, and pink snow mold. Statistical data can be found in Table III.2.1.



Aug 19, 1992

Aug 6, 1993

Apr 28, 1994

July 11, 1994

Figure III.2.3. Clover frequencies (%) in the mixture plots in 1992, 1993, and 1994. Statistical data can be found in Table III.2.1.

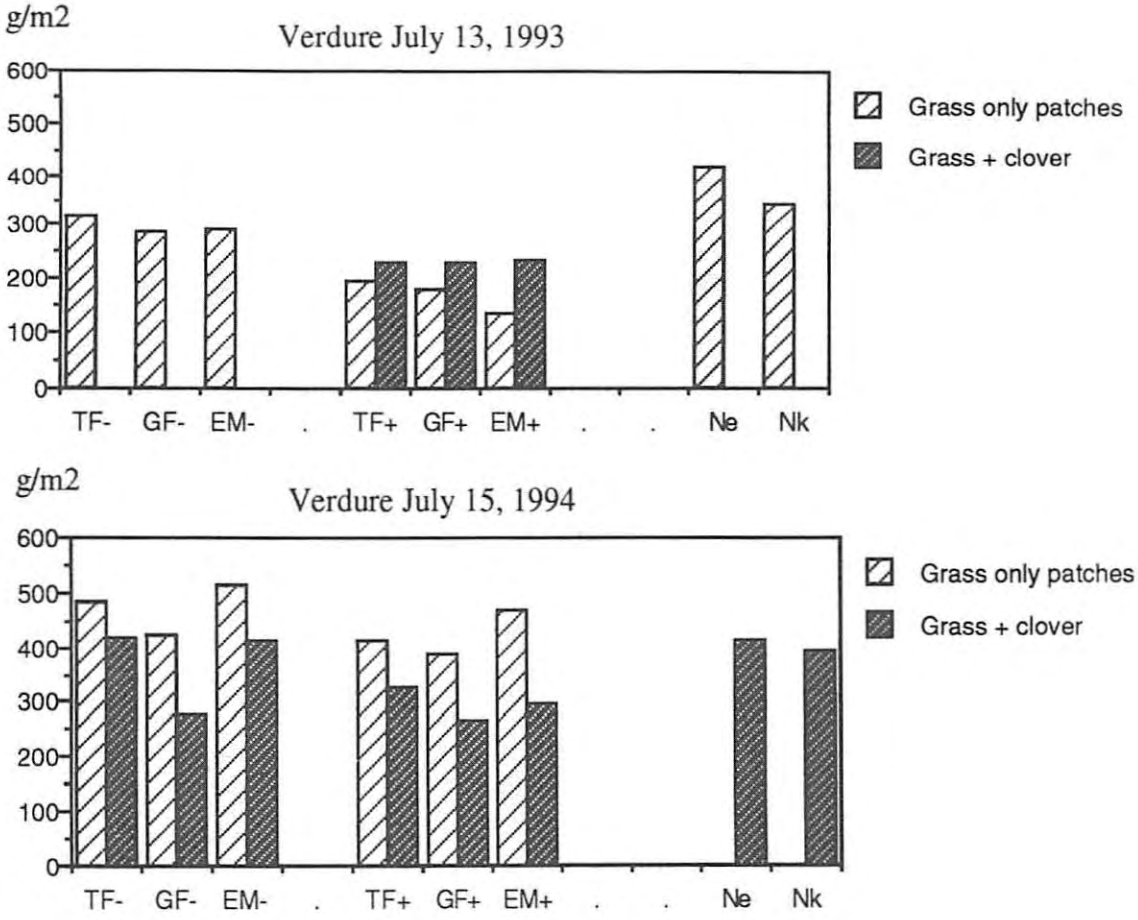


Figure III.2.4. Verdure in the mixture plots and NPK in 1993 and 1994.

Statistics

July 13, 1993

F clov (1,2): 11.1, p=0.0793
F mix (2,8): 0.14, p=0.868
F clov*mix (2,8): 0.15, p=0.862

cv clov = 15.4%
cv mix & clov*mix = 20.1%

F clov patch (1,6): 6.72, p=0.0411

F Ne/Nk (1,2): 19.6, p=0.0474
cv Ne/Nk = 5.46%

July 15, 1994

F clov (1,2): 1.95, p=0.297
F mix (2,8): 0.90, p=0.442
F clov patch (1,10): 9.70, p=0.011
F clov*mix (2,8): 0.31, p=0.742
F clov*clov patch (1,10): 0.00, 0.958
F mix*clov patch (2,10): 0.34, p=0.720
F clov*mix*clov patch (2,10): 0.39, p=0.688

cv clov = 26.4%
cv mix = 33.1%
cv clov patch = 23.6%

F Ne/Nk (1,2): 0.86, p=0.452
cv Ne/Nk = 6.34%

Table III.2.1. Statistical data for various variables presented in Figure III.2.2.

Variable	Date	Clover F(1,2):p	Mixes F(2,8): p	Clover*Mixes F(2,8): p	cv Clover	cv Mixes& Clover*Mixes	Ne vs Nk (Total) F(1,2): p	cv (Total)
Chlorophyll	June 11, 1993	3.56; 0.200	0.42; 0.672	0.86; 0.459	6.30	8.24	No Statistics	
	July 7, 1994	0.21; 0.688	1.80; 0.226	0.22; 0.804	5.73	8.46		
Winter injury (arcsine)	May 17, 1993	3.34; 0.209	0.32; 0.735	1.36; 0.308	43.6	31.9	1.00; 0.423	54.3
	April 28, 1994	0.28; 0.651	35.2; 0.0001	8.24; 0.0114	42.8	31.5	0.00; 1.00	63.1
Red thread (arcsine)	Aug. 5, 1993	28.0; 0.034	0.34; 0.722	0.19; 0.827	56.2	128.1	0.47; 0.562	174.2
	April 28, 1994	0.04; 0.864	0.33; 0.729	0.12; 0.892	153.1	70.4	36.3; 0.026	40.2
Clover (arcsine)	Aug. 19, 1992	18.78; 0.0005	12.75; 0.0033	12.75; 0.0033	4.83	3.42	0.49; 0.553	96.8
	Aug. 6, 1993	14.90; 0.061	0.012; 0.988	0.301;0.749	46.5	47.1	0.11; 0.774	47.7
	April 28, 1994	0.06; 0.828	3.07; 0.103	3.21; 0.095	121.2	33.3	6.23; 0.130	23.7
	July 11, 1994	143.0; 0.007	1.09; 0.381	2.77; 0.122	6.63	14.5	4.80; 0.160	7.44

Table III.2.2. Species composition of mixes. Values are arithmetic averages of visually estimated percent cover for each component.

		Mixture			Grass Component			
Year	**Mix**	**Grass**	**Clover**	**Weeds**	**TF**	**Ktb**	**Rye**	**Fes**
1993	TF-	86	13	1.0	100	0.0	0.0	0.0
	GF-	93	7.0	0.0	0.0	26	63	11
	EM-	95	4.0	1.0	0.0	42	46	12
	TF+	68	30	2.0	70	3.0	24	3.0
	GF+	51	47	2.0	0.0	34	57	9.0
	EM+	59	39	2.0	0.0	31	59	10
	Neco	96	3.0	1.0	0.0	45	41	14
	Nktb	94	6.0	0.0	0.0	100	0.0	0.0
94/95	TF-	87	11	1.0	81	8.0	10	1.0
	GF-	95	5.0	0.5	0.8	39	49	11
	EM-	92	7.0	1.0	1.3	35	47	17
	TF+	88	10	1.0	52	15	24	9.0
	GF+	84	15	1.0	0.7	30	50	19
	EM+	88	11	1.0	0.0	28	40	32
	Neco	80	19	0.5	0	59	24	17
	Nktb	70	29	1.0	.	.	.	.

Table III.2.3. Estimated[1] percent cover of ground by tall fescue in early June of 1993 and 1995.

	Minus Clover Plots		**Plus Clover Plots**	
Block	*1993*	*1995*	*1993*	*1995*
1	65	80	7	5
2	96	69	47	54
3	98	80	88	83

1 Estimated for 1993 by multiplying %grass in mixture by %TF in grass component/100 (from the data set used for Table III.2.2); in 1995, %clover was recorded but not percent grass or weeds, thus %TF was estimated as (100-%clover-2%), assuming that weeds were 2%.

IV. GENERAL DISCUSSION AND IMPLICATIONS FOR MANAGEMENT

The research reported in this report was conducted under wholly organic conditions, but presents information that has applications to any turf system for which reduced inputs and a greater degree of ecological sustainability are being sought.

Hill (1985) and MacRae et.al. (1990) describe the transition to sustainable agriculture as occurring in three phases:

(1) efficiency, in which increased efficiencies result in reduced inputs and waste,

(2) substitution in which benign inputs are substituted for toxic or ecologically disrupting inputs, and,

(3) redesign where the internal structure is redesigned so that there are less needs for inputs of any kind.

To give an example from pest control; initially, a synthetic pesticide with toxic effects on non-target organisms is being applied routinely at a certain developmental stage of a crop to prevent infestation by a serious pest. Stage 1 - *efficiency or reduction* - might be represented by monitoring the pest, and weather conditions favoring the pest, and applying pesticide only when it is certain that without it, the pest will reach destructive numbers. Stage 2 - *substitution* - might be represented by using a more innocuous control agent, for example a biological pesticide such as B.t. Stage 3 - *redesign* - might involve diversifying the system through intercropping and establishing windrows in order to increase the numbers and types of natural enemies of the pest within the system.

These stages do not necessarily occur in the stated sequence. In the case of fertilizer management, it is common to substitute organic fertilizers for synthetic fertilizers before reducing rates of application. Amounts of fertilizers required to ensure maximum yield of a crop or high quality turf are well documented, e.g. in the case of turf, typically 3-5 lbs of N per 1000 sq ft per annum. Often the initial step taken in moving towards more sustainable fertilizer management is to add enough organic fertilizer to supply the same amount of N as had been applied by the synthetic fertilizer. Often, this means applying more N in total than was applied as synthetic fertilizer because of the lower short term availability of the N in the organic fertilizer.

Whether one is using synthetic or organic fertilizers, when fertilizer is being applied according to the established norms for rates, there is some and in some cases a large, potential for reducing the amount of fertilizer applied. This is because the recommended rate is the lowest value for a wide range of soils that gives maximum or near maximum yields (Fig. IV.1). This means that in most cases - whether one is applying an organic fertilizer or synthetic fertilizer - the real minimum requirement is lower than the recommended value. Thus reductions can almost invariably be achieved by simply applying less, and seeing what happens, i.e. experimenting. Such experimentation does not have to be conducted on a whole property; it could be done in a strip for example, and if it works, reduce the application to the entire property the following year, and try again a further reduced application. The benefits of reduction accrue to both the user and the environment. For the user the benefit is lower cost. For the environment, the major benefit is greatly reduced loading of nutrients into ground and surface waters (most of the pollution results from applying nutrients at rates greater than the real needs (Fig. IV.1; Keeney, (1982)). It is important to realize that organic fertilizers, overused, can be just as polluting of the environment as when conventional fertilizers are overused; thus regardless of which type, it is desirable to use the minimum possible.

Redesign in the case of turf management could involve introducing clover to the system, and using species and mixtures of grass that require less fertilizer. These are more fundamental changes that move the system towards a condition of greater self regulation and better adaptation to the native environment.

Lying somewhat in between reduction and redesign are modified management practices that can improve the health of grass and reduce needs for fertilizer, e.g. aeration, dethatching, and mulch mowing. When such practices are introduced, their full benefits will only be realized if fertilizer applications are in turn reduced. As there are no simple formulas for that, then again the user must experiment a little.

The research in this report has focused on reduction and redesign aspects of the conversion towards more sustainable turf management[1]. Our research does not

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[1] The Oaks experiments did not deal much with the substitution aspect. We did not screen a wide range of alternative fertilizing materials, or a large number of grass cultivars and mixes. In regard to different types of fertilizing materials, we refer the reader to the comments in Box 2 - it is our experience that organofertilizers, defined as they are in that box, behave similarly. Bulky amendments often do not, but their properties are reasonably well predicted from test values for %N, C:N ratio, inorganic N, maturity and phytotoxicity. There is an extensive literature on this topic (see for example Mathur, et.al., 1993). In regard to grass cultivars and species, we are able on the basis of the research to make some generalizations about species, and mixtures of species which should be applicable to other temperate regions. The behavior of the specific cultivars that we used, however, could differ significantly in other regions.

eliminate the need for users to experiment. Rather what we are able to provide, based on the improved understanding of these systems that was gained from the research, and on specific experimental results, are *provisional guidelines* for users who want to reduce inputs to their systems and make greater use of alternative materials.

In this section, we discuss the results in the context of their potential use in organic management of turfs. They are discussed in categories in which they are commonly placed, and in a sequence which we suggest is a logical way to think about management of turfs: soil audits, bulky soil amendments, species and mixtures, top dressing of organofertilizers, and other maintenance factors (disease, mowing, weed control). We are not addressing all of the factors that should be considered in each of the categories, but rather, those upon which the results of this study have some bearing.

We emphasize that we are discussing implications for management, and that the suggestions concerning rates, timing, and management methods must be considered provisional, and subject to modification by the individual user according to his or her experience with individual systems, and/or in the light of more scientific data. The management implications should be seen as a basis for experimenting, rather than as a set of thoroughly validated techniques. The individual user might choose to experiment on a smaller or larger scale - we do think the provisions are sound enough that there is not a lot of risk in trying them. With time and more research, the scientific base of organic management will improve, and with it the certainty of such recommendations. Regardless of the scientific base, however, monitoring, understanding of the underlying processes, and experimentation by users is essential to achieve maximum ecological efficiency.

In the discussion below, highlights are bolded. Reference is made to Figures and Tables for readers who want to refer to the pertinent data, however, this discussion is intended to be readable without having to refer back to the results. Photos are likewise cited.

Soil audits

Data from soil analyses are relied on to predict requirements for nutrient supplements, usually with the exception of nitrogen. Yet rarely are the recommendation protocols calibrated for particular situations, and recommendations for nutrient supplements can vary widely between labs (Donald and Warman, 1992; De Vault, 1982 a,b,c).

There is a growing trend in farming systems to use a combination of nutrient budgeting and soil tests to predict nutrient needs in order to reduce the excesses which contribute to pollution of surface and groundwaters (Lanyon, 1992; Haynes and Williams, 1993). The underlying assumption is that the requirements for nutrient supplements are equal to amounts lost from the system. When nutrient levels are initially low, higher amounts will have to be applied than are removed in order to increase the steady state values of the nutrient reservoirs. Not well understood is the question of what nutrient level should be maintained in the soil, or to what level they can be reduced without losing productivity. This is a critical issue because, in general, losses can be expected to be higher with increasing size of the nutrient reservoir. Also, high levels of certain insoluble nutrients inhibit biological processes that make insoluble or poorly available nutrients more available, thereby creating an artificial demand for higher levels of fertilization. Thus nitrate at very low levels suppresses nodulation and nitrogen fixation of legumes, and high levels of inorganic phosphorus inhibits infection of root by mycorrhizae (mycorrhizae enhance ability of plants to take up P and trace elements; they can also increase pest resistance and drought tolerance). ***In principle, organic systems should operate with the lowest levels of soluble nutrients that allow near maximum productivity or quality.***

In this study, our standard soil analyses were performed by a large commercial laboratory that is widely used by farmers in Canada, including the Maritimes, and that has a reputation for reliable analyses and conservative recommendations for fertilizers. They use a Mehlich III extraction for K, Ca, and Mg, and P for Maritime soils. This extractant is widely used for soils in the North Eastern United States (Northeast Coordinating Committee, 1991) and in eastern Canada (Donald and Warman, 1992). They estimate the cation exchange capacity (CEC) from the sum of the cations and a measure of acidity, and calculate percent saturation of Ca, Mg and K in order to take into account differences in nutrient holding capacity of soils. Organic matter values are measured by a chemical oxidation technique and are taken into consideration when estimating needs for N. We believe that the ratings of the soil nutrient levels and recommendations they make for supplements are representative of what a user will get from a reliable soil testing laboratory (Table J1).

In general, ratings are applied to a wide range of conditions with bias towards overestimating actual requirements in order to ensure that no crops are underfertilized. Thus one would anticipate modifying ratings upward when site specific calibrations are made; i.e. that a given level of a particular nutrient will be rated higher when the user has site specific and crop specific information (see discussion in Section III.1J).

In principle, one might expect as well, that ratings for soils from systems in stage three of the "reduction-substitution-redesign" scheme of MacRae et.al. (1990) (i.e. from organic systems in which a high degree of self regulation operates, or for soils with high soil organic matter in which there is a high flow of nutrients through the organic reservoir) would be higher than ratings for a conventional systems. As an exploratory or preliminary examination of this question, we used the data on tissue nutrient concentrations to rate adequacy of P, K, Mg and Ca in turf grass, and compared those assessments to the soil ratings provided by the commercial lab (Section III.1J). Based on this comparison, and taking into consideration mobility of the nutrients in the soil, ***we make some provisional recommendations on interpretation of soil tests; those apply to organic turf systems in which there is a mixed sward (not pure Kentucky bluegrass) and clippings are recycled by mulch mowing.***

Phosphorus. Soil analyses for P have been used locally to indicate need for P on turfs draining into lakes; where soil P is not deficient, it is recommended not to apply P in order to minimize possible runoff of P into storm sewers and lakes. In a pilot project of 28 turfs in one neighborhood, only two were identified as low in P (Loucks, et.al. 1994). In the present study, soil P levels varied from 2 to 445 ppm Mehlich-III P; remarkably, even at the site of near-zero soil P, leaf P levels were in the sufficient range (Figure J1). We conclude that a lot of the P cycles through the organic P fraction, which is not included in the Mehlich III method.

In principle, in a organically managed system where clippings are recycled, there should be an extremely low rate of P loss; further, managing the soil to maintain high biological activity, should help to mobilize P. Thus except where soils are strongly P deficient or are P-fixing, there is unlikely to be a high demand for P. There is as yet no organic-P test which has been widely adopted by soil testing labs, although it is acknowledged that is needed. ***In lieu of that, we suggest that low of no P be used and/or that clippings be analyzed for P in cases where P limitation is suspected.***

Potassium. Potassium is highly mobile in soil, and inevitably, a significant amount is likely to be to be lost by leaching. In some cases, low rate of loss may be fully compensated by release from non-exchangeable K fractions, and weathering processes. Although not well documented, there is some evidence that organic systems make potassium more available or increase weathering rates (Measures, 1989).

Our provisional calibration suggests that at The Oaks, K would become limiting when soil K drops below about 40 ppm, which is considerably lower than the commercial lab's upper limit, approximately 100 ppm, for a "low" rating (and circa 80 ppm for the upper limit for a "very low" rating).

Magnesium and Calcium. One school of thought in soil sciences which has been widely followed in alternative agriculture and horticulture, places a lot of emphasis on the balance of the cation exchange complex by K, Mg and Ca; frequently quoted desirable ranges are 2-5% for K, 5-15% for Mg and 65-75% for Ca with 10-15% for H^+ (Walters and Fenzau, 1979; Mclean, 1977) We found that ***5% Mg in the soil CEC did correspond to the approximate critical concentration in grass tissue. However for Ca, there was no evidence for Ca limitation, or overall for general quality problems on the B field, even though in 1993 and 1994 percent saturation of most samples was less than 60%.*** None of the leaf Ca values were below the OMAF lower critical value of 0.2% Ca even when %Ca on the cation exchange complex was close to 20%, and only a few were below the value of 0.5% quoted by Jones (1980) (Figure J1). ***For a mixed sward such as Ecomix, at least, it appears that Ca per se was not limiting at % saturation values well below 65%. It is probably more critical to maintain higher saturation when the sward is predominately Kentucky bluegrass (Watschke and Schmidt, 1992). Low values could also be more critical for clover (Blue and Carlisle, 1985), and are associated with low pH which may cause aluminum and manganese to reach deleterious levels.***

Because organic systems tend to be better buffered than chemical systems when mineral-N is being used, pH changes occur more gradually (Patriquin, et.al., 1993). In such systems, coarse limestone can be used to maintain pH over longer periods. The B field had a pH of 4.9 before it was renovated for the experiment. ***We added lime at about twice the amount usually advised (which is to add not more than is required to raise the pH by one pH unit at any one time), with half of it in fine grade lime, and half very coarse. pH, base saturation, and exchangeable Ca and Mg increased gradually over the three years (pH went from 5.5 in fall 1992 to 6.1 in fall of 1994, Ca from 42% to 62% saturation).***

Nitrogen

Soil tests such as the release of nitrate when soil is incubated, or the amount of NH4-N extracted after boiling (Gianello and Bremner, 1986), have been developed that can predict N supply fairly accurately, however, they require at least annual sampling and the predictions are dependent on good calibration data. Where one is dealing with different soil types, this is a serious limitation. A separate study of 22 soils from Metro turfs suggests (M. Hope Simpson and D. Patriquin, unpublished) that soil organic matter is a fairly good predictor of the short term N supply (Fig.IV.2), and there are good theoretical grounds for such a relationship. The greater need of the F field for N supplements compared to the B field, is most readily explained as due to differences in soil organic matter and release of N. ***Thus we suggest, provisionally, that soil organic matter can be used as a first approximation in estimating soil N supply***. This topic is discussed further below. If soil organic matter is to be monitored, it is very important that an appropriate technique is chosen. For example, soil analyses performed in Nova Scotia by a combustion method overestimated actual soil organic matter (Donald and Warman, 1992) and this would need to be taken into account in comparing other soils to those in the present study.

Electrical conductivity as a measure of coupling

Electrical conductivity (EC) is used primarily to monitor salt accumulation in soils receiving high salt loadings (e.g. through heavy use of synthetic fertilizers) and/or where evaporation tends to concentrate salts. Patriquin et.al., (1993) suggested on theoretical grounds that EC might be used under normal conditions to monitor the coupling and decoupling of the soil-plant system. Plants are able to take up nutrients from very dilute solutions, thus in closely coupled soil-plant systems, free ions (and EC) are reduced to very low levels. This can occur without nutrient limitations providing there is a continuous replacement of the ions taken up through regenerative processes in the soil. If soluble fertilizers are applied in excess of needs, or organic fertilizers release nutrients in excess of needs, EC will increase. In this study, the EC increased when soil was originally cultivated in 1992 but by 1995, the EC had returned to close to original values (Fig. I3). During the same period, the verdure and clippings increased. ***These observations and the theoretical considerations (Patriquin et. al., 1993) suggest that EC could be used as a diagnostic tool in organic systems***. It could for example be used to indicate sites of over fertilization. For example in shady situations where the need for fertilizer supplements may vary considerably according to whether or not trees are competing with turf for available nutrients and if it is not clear which is the case, high EC values could indicate that previous fertilizer use was excessive. An important advantage of this method is that the apparatus is inexpensive, the measurement is simple, and it could be performed readily on site.

Bulky amendments

When a new turf is established, either from sod or by seeding, there is a one time opportunity to add bulky amendments directly to the soil. Bulky amendments are usually added to provide a quick improvement of soil quality including improved water holding capacity and aggregation of soil particles (tilth), which affords in turn better drainage, aeration and the physical environment for root growth. They also add nutrients, but that is not usually the primary reason for adding bulky amendments. To the extent that nutrients supplied in the bulky amendments can be fully utilized, however, top dressings of fertilizer can be subsequently reduced, making the other benefits of the bulky amendments more economical. We examined two bulky amendments that were available at the time that the experiment began, (i) potato compost, - a processed, moderately expensive waste product, and (ii) brewery waste (spent grain) from a local brewery, an unprocessed, and relatively inexpensive material in comparison, based on N content (Table II.2; Photo 1a).

Potato compost

Potato compost was the only amendment except for mushroom compost that was available in bulk at the beginning of the experiments. The latter was not used because of its high salt content and other difficulties that render it problematical (Luhr, et.al., 1984; Wang et.al., 1984). The process for potato composting had been developed in PEI with the cooperation of government, and consultation advice from US composting experts. The compost was prepared from potato culls, farmyard manure, soil, and sawdust. It was applied at The Oaks at a rate of approximately 98 t per ha.

Benefits or potential benefits of the compost that were documented in this study included:

(1) ***Provision of the equivalent of 1 - 2 lbs N*** in second and third years with values in the lower part of this range on the F field, and the higher part of the range on the B field (Section III.1A,B).

(2) ***Provision of large amounts of P and K;*** the effects on the Mehlich III soil P persisted over the three years and would probably persist much longer. Potassium was still above the control in 1994, but would likely drop to close to control values within another year (Figure I6).

(3) ***It increased resistance to red thread*** (Figures F1, F2).

(4) There was some indirect evidence that ***it improved water status*** of the soils.

(5) ***It increased pH on acid soil*** (Figure I6).

Problems encountered with the compost were primarily:

(1) ***It was very hydrophobic***, and was difficult to wet thoroughly once it dried out during the particularly dry weather in early summer of the establishment year.

(2) ***It appeared to immobilize N and/or have phytotoxic effects*** on the B field turf in the first year (Figure B4; Photo 4d)

(3) ***By the second and third years, it stimulated top growth excessively and would have required more frequent mowing than other treatments*** (Section III.1A) (We did not mow more frequently in order to maintain the same maintenance regimes for all treatments, but mowing was noticeably slower on the compost plots on the B field).

If the use made of the compost at The Oaks was intended to be a practical one, it would be assessed as of very low value on the B field over the three seasons of the experiment. It reduced greenness in the establishment year compared to the control (Section III.1B), and increased it subsequently due to release of N, however, soil without amendments provided adequate N through most of the season anyway, and application of 1/2 lb N as organofertilizer in the fall of 1992 sufficed to make up for early season N deficiency in 1993. The B field had adequate K and P without compost. It is probable on the other hand, that the compost would maintain a high quality turf (without fertilizer top dressing) in subsequent years, longer than might be the case without compost. Further, if its properties were anticipated, it might have been possible to use it to advantage in this sort of situation, as it did produce a very dense, healthy looking turf. If it were applied at about 50 t per ha (instead of 98), providing some supplements (organofertilizer or brewery waste) in the first year to overcome immobilizing effects, then it would produce in this situation a very high quality turf which could be maintained for perhaps five years without further supplements.

While there was a strong response to compost on the B field, on the F field, which was a poor soil, the response to compost was weak, or subtle. In the summer of the establishment year, soil amendments negatively affected (compost, spent grain, NPK) or had no effect (organofertilizer) on greenness and verdure compared to the control (Section III.1A,B). In the second year, the Cp main plot was not overall darker green than the Cn main plot. In the third year there was a weak improvement but it was not sufficient on its own to give a high quality turf. The compost treatment did reduce disease in the second and third years, however, not more than did organofertilizer at the 3 lb level without compost (Section III.1F). Thus it appears in total, that compost on the F field did not provide significant advantages over those provided by organofertilizer alone; were this a commercial situation, it seems in retrospect that it would not have been economical compared to use of organofertilizer alone.

A priori, we expected the compost to have pronounced, positive effects on a low fertility soil such as the F field. That it didn't, we believe, was due to the compost, as received, being immature (incompletely composted), and to the F field soil having relatively low biological activity. The compost had a relatively high C:N ratio (22.3-26.7:1; Table II.2) and this value is slightly below the value usually cited as required for immobilization properties (i.e. about 33:1), but is well above values for mature compost (< 20:1) (Bartholomew, 1965; Mathur, et.al., 1993). Tests conducted in the lab (not part of The Oaks experiments) revealed it to have phytotoxic properties, high respiration, high light absorption at 665 nm, and N-immobilizing properties, which are all characteristic of immature compost (Mathur et.al., 1993; Schnitzer et.al., 1993).

The immobilizing qualities of compost observed on June 29, 1992 on the B field were not observed on the F field (Figure A1). This could be because the F field had higher levels of soluble nutrients at that stage, however, that is an inferred, not a measured quality. In 1993 and 1994, there was some evidence for stimulation of grass quality by compost on the F field but not as much as on the B field. Rough calculations of the proportion of organic matter supplied in compost that was remaining after three seasons, suggested slower breakdown of compost on the F field than on the B field, presumably because of lower inherent biological activity (Table I14), and because soil moisture conditions were likely also less favorable for high biological activity.

The initial, immobilizing and possibly phytotoxic effects of compost on the B field were predictable from the quality measurements on compost cited above. What would not have been anticipated, even given those qualities, was the apparent increased mineralization compared to the control that began in the second half of 1993 and persisted through 1994. The laboratory incubations of soil collected at the end of 1994 illustrated slightly increased N supplying capacity in compost plots compared to control. There is not a lot of information in the literature on the long term turnover of material that is initially immobilizing, however, the generally held concept seems to be that after immobilization ceases, mineralization resumes, but at rates not much greater than that of soil that did not receive immobilizing residues initially (Black, 1968). Such materials will contribute to the more resistant humus pool and increase N in that way, however, this is an incremental effect spread over the long term, and so is not large within a single year. On the B field, however, there were clear phases of immobilization (summer 1992), near neutral effects (fall 1992 through to mid season 1993), and strong stimulation of turf growth (mid-season 1993 to the end of the experiment) by compost added before turf establishment in 1992.

These observations suggest that for composts to be most beneficial on soils of low biological activity (indicated by low percent organic matter, light color, weak humic odor and poor tilth and as available, bioassay data), the compost should be fully mature (see Mathur, et.al., (1993) and Schnitzer et.al. (1993) for discussion of criteria of maturity). Alternatively, they should be supplemented at incorporation with organofertilizer at circa 3 lbs N per 1000 sq ft, or with a material such as spent grain. ***A provisional guideline*** for quantities would be those applied to the mixture plots at The Oaks, i.e. 100 t/ha compost, + 3 lbs organofertilizer-N incorporated, or spent grain at circa 4 lbs N per 1000 sq ft (compost + brewery waste was applied to part of the F field that was not in the experiment; this section exhibited excellent greenness and good density (Photo 5c).

On soils of higher biological activity, immature composts might have some benefit for a site that is being planned for the long term. In that case, supplements can be provided to counteract initial immobilizing effects.***To avoid excessive (rank) growth, the application rate of composts to soils of high soil organic matter (>5%) should be reduced to circa 50 t per ha or less if the compost is mature when applied; there will likely be ample N in the first year without amendments (Iglesias-Jimenez and Alvarez, 1993).***

The use of immature composts in planting beds should be less problematical because the high biological activity in beds would tend to turn composts over quickly, and because there are opportunities to add other materials to the soil to mitigate any undesirable effects observed in the short term. Immature compost could be added with organofertilizer supplements for example, or as a mulch in the fall. ***What's important is that the composts are tested in order to predict best immediate use or need for further turning and storage prior to use.*** When immature composts are added repeatedly to beds, those beds should be monitored for EC and/or nitrate as at some point, they will likely start to release a lot of inorganic N (Patriquin et.al., 1993).

Brewery waste (spent grain)

Brewery waste on the B field behaved like an organofertilizer, with a large short term release of N, rather than like a bulky amendment with a more sustained slower release. This is what would be predicted based on its relatively high (5.3%) N and low lignin content. In general, as %N of organic materials increases, the proportion of the contained N that mineralizes in one season increases, and the carryover to the second and third years decreases (Mathurs and Goss, 1979; Quenada and Cabrera, 1995). The content of lignin is also a factor, short term release decreasing with increasing lignin (Fox, et.al., 1990)

The short term fertilizing effect of BW was pronounced on the B field in the first year, and persisted into the second year, however by the third year, BW plots appeared to have lower turf quality than controls (Section III.1A,B). On the F field, a short term fertilizing effect was not evident in the summer of the first year, but neither was it for NPK. By the second year on the F field, the NPK treatment had a strong effect on greening and verdure; there was some positive effect of brewery waste. It seems likely that N released in the first year was mostly lost by leaching (fields were irrigated frequently in the establishment year). In the third year, on the B field, grass on BW plots (without organofertilizer) appeared lighter green than the control treatment. Soil organic matter, alkaline P-ase activity, respiration and pH were also reduced compared to the control (Tables I6, I13). There were similar but more pronounced effects of NPK treatments, which also had significantly increased bulk density by the end of 1994 (Table I2), i.e. there was evidence for both BW and NPK treatments that by the end of the third season, they had led to some deterioration of soil quality, and of the productive capacity of the soil in comparison to the control treatment.

Such negative effects could be attributable to one or more of the following:

(1) Release of an excess of N as nitrate in the first year followed by some leaching which would result in acidification of soil (Patriquin et.al., 1993).

(2) A "priming" effect sometimes associated with high N (Davidson, 1978; Azul, et.al., 1994) or with organic materials that decompose quickly (Hahne, et.al., 1977; Jenkinson, 1981) which accelerates breakdown of soil organic matter.

(3) High N can result in reduced root growth (Davidson, 1978) which in turn would lower soil organic matter, and possibly increase bulk density.

Interestingly, unusually high aluminum concentrations were found in grass from some BW and NPK main plots in 1993. This could have resulted from localized acidification associated with nitrification (low pH can bring certain heavy metals into solution.).

Two important conclusions in regard to the brewery waste are:

(1) ***BW behaved like an organofertilizer rather than like a bulky amendment***, releasing a lot of N over a short period;

(2) ***The detrimental effects of applying BW were a result of an excessive rate of application compared to the capacity of the system to take up N. This was an example of over fertilization using an organic material.*** It is noteworthy that grass on the BW plots attracted the most favorable comments at the 1992 field day (held Oct. 5, 1992) and that the deleterious effects were not really evident until two years later. It is likely that any organofertilizer used at the same level as the spent grain would have had similar effects.

Grass species and mixes

Below, we comment first on individual species, and then on mixtures.

Kentucky Bluegrass

Kentucky bluegrass is the mainstay of the turf industry in temperate climates. Kentucky bluegrass (Haga) was 40% of the Greenfast mix, 20% of Ecomix, and was planted in blended stands in NPK subplots (50% Haga, 50% Gnome). This species proved to be the most susceptible to diseases, which included red thread in 1993, anthracnose in 1994, and two leaf spot diseases in both years (Section III.1F; Photo 13). Kentucky bluegrass is reported to be more resistant than other species to red thread (OMAF, 1981). We also discovered a root pathogen on Kentucky bluegrass plants, previously reported not to occur on this species (Photo 12c). Red thread and anthracnose are known to respond negatively to added N, and both were reduced in abundance at higher levels of organofertilizer (Figures F1, F5). Thus an explanation for the exceptional susceptibility of Kentucky bluegrass compared to other species, could be that it was stressed at the lower levels of organofertilizer while the other species were not. It was also noted that during dry weather, Kentucky bluegrass was lighter green than perennial ryegrass.

On the plus side, Kentucky bluegrass exhibited very good winter survival in 1993 and 1994 (Figure III.2.2); the Kentucky bluegrass plots were the darkest green in early spring. However, in 1994/5, when no fall fertilizer was applied, the Kentucky bluegrass plots appeared very poor in the spring and exhibited a peculiar reddening and some necrosis of distal parts of leaves (Photo 13d).

Curiously, the Kentucky bluegrass subplots in the NPK main plots proved to be highly susceptible to clover invasion, especially when fertilizer was not applied in the fall of 1994/spring of 1995 (Section III.1C). The Kentucky bluegrass subplots were also heavily invaded by *Agrostis* sp. in the second year (Photo 9e). According to Watschke and Schmidt (1992), Kentucky bluegrass is less susceptible to bentgrass invasion when it is limed to pH 6.5 (from an initially lower pH); also, high levels of N make Kentucky bluegrass more competitive with perennial ryegrass and fine fescues.

We conclude that ***pure stands of Kentucky bluegrass are very unsuitable for organic systems because of their high susceptibility to invasion by competing species, and their susceptibility to diseases at levels of N and lime that do not render other species susceptible.*** On the other hand, their winter hardiness is a plus and they contribute to diversity of the broader leafed grasses. In mixes, there was apparently some complementary interaction between perennial ryegrass and Kentucky bluegrass, the perennial ryegrass being relatively more successful at higher fertility levels in the first year, and Kentucky bluegrass catching up subsequently. Probably cultivars could be identified or developed, that are less demanding of N. In one study locally, we found Kentucky bluegrass to be the most important grass on minimally fertilized native pastures that had been improved through rotational grazing; wild white clover was also abundant (N. Hill and D. Patriquin, unpublished data).

Perennial ryegrass

Perennial ryegrass performed exceptionally well in these systems, growing rapidly in the first year as is its reputation, and, unexpectedly, exhibiting high survival into the 4th season (1995). It suffered no peculiar diseases, and was not the focus of initial infestation of several diseases, as was Kentucky bluegrass. It maintained greenness better than Kentucky bluegrass during droughty periods and overall blended well with clover.

Fine fescues

We did not distinguish between species of fine fescues (chewings, creeping and hard fescues were included in Ecomix), however, in pure stands, the Reliant hard fescue exhibited very poor winter survival and that likely accounted for the large winter injury in Ecomix in 1992/1993. The Reliant was recommended because it is considered a good low maintenance grass which commonly used on highway verges. We could not locate any data on testing of the cultivar locally, although it is used locally. ***This illustrates that regardless of the type of management, it is probably unwise to seed any cultivar in a high proportion without some knowledge of winter hardiness.***

The fescues appeared not to be affected by fertility levels.

Tall fescues

The tall fescues produced a turf that even at 80% purity, attracted favorable comments from visitors to The Oaks, who liked its texture, thickness and color (Section VII-Appendix 2A; Photo 15b). However, the tall fescues suffered high winter injury (Figure III.2.2), late fall bleaching of leaves (Photos 14c,d), susceptibility to pink snow mold (Photo 14a), and poor overall appearance for the first month in the spring. They exhibited very poor persistence on two of the six test plots, both of them plus clover plots that did not receive organofertilizer. ***Presently, these varieties cannot be recommended for use in pure stands under organic management.*** On the other hand, a mix of 35% tall fescue and 65% Greenfast planted in the fall of 1993, proved highly attractive through the seasons of 1993, 1994 and 1995 and received high ratings from visitors (Section VII-Appendix 2A). The tall fescue component should be seeded separately from other species in a mix, as the seed tends not to distribute well within a seed mixture (related to seed size and number).

Mixtures

The two monoculture blends that we tested (Kentucky bluegrass and tall fescues) had definite drawbacks as cited above. Greenfast exhibited better winter survival than Ecomix in 1992/93 because of a higher Kentucky bluegrass component and lower Reliant hard fescue component (Figure III.2.2). On the other hand, it was less attractive in mid-summer because of more anthracnose (associated with Kentucky bluegrass). ***Based on the these observations, for organically managed turf locally, we recommend a mixture of 20% Kentucky bluegrass, 30% ryegrass, and 50% fine fescues, with 25% each of the creeping and chewing varieties.*** A mix of this nature with 35% tall fescue also appears to be a good one, but some further trials would be appropriate.

Clover

A major decision in organic turf management is whether to include or encourage or not to include or encourage, white clover. Since at least the 1950's, clover has been regarded as a weed in turf, and virtually no attention has been given to its management, or to our knowledge, to selection of cultivars for turf (Waddington et.al., 1992). Wild types are common in eastern Canada. Dutch white clover of no particular pedigree is available from most seed houses.

There turned out to be a large seedbank of clover in the B field, and its differential development in the different fertility treatments provided considerable information on factors affecting its abundance. On the F field, in contrast, it developed from the clonal type patches that are considered unsightly (Photos 5a, 7a). By making observations on patches within subplots where clover was present or absent, we were able to discriminate some of the effects of clover on turf quality. Visitors to The Oaks gave us independent assessments of its aesthetic appeal or lack thereof (Section VII-Appendix 2A).

There can be little doubt that clover offers many benefits for organically managed turfs; features that we documented or have inferred from The Oaks experiment include:

(1) ***Presence of clover conferred greater disease resistance*** to associated grasses (Figure F2).

(2) ***Clover provided the equivalent of up to 1-2 lbs N per 1000 sq ft.*** These values are consistent with N_2 fixation input documented by Vessey and Patriquin (1984) for white clover on pasture and turf in Nova Scotia (for three systems with mid-summer cover of >50%, N_2 fixation was estimated as 66-100 kg N/ha per year). N_2 fixation by clover, and feedback control of nodulation and N_2 fixation by ammonium and nitrate, and the cycling back and forth between clover and grasses over time (Turkington and Harper, 1979), provide self regulating control over the supply of N in the turf system. That in turn minimizes losses of cations via leaching.

(3) ***Clover was probably an important factor in the effective control of broad leaf weeds at The Oaks*** - this was suggested particularly by the very low weed cover in NPK plots in 1995 after weeding was interrupted for most of the season (Table C2). These plots also had exceptionally high clover abundance.

(4) ***Clover was probably a factor contributing to maintenance of greenness through the entire growing season in 1993, 1994 and 1995,*** with no auxiliary watering in the previous two years. (In 1993, we watered after several days of dry weather in June and July, to aid in establishment of grass overseeded into winter injured patches). In the late summers of 1994 and 1995, Edmonds employees reported that the only property maintaining high clipping yield though August without frequent watering was The Oaks B field.

The disadvantages of clover appear to be mostly aesthetic: white flowers are considered displeasing; and as we described in Box 4, the contrast of green clover patches against browning grass backgrounds in mid-summer are unsightly. The white flower problem is reduced to some extent when the turfs are mowed higher than usual but more frequently (typically 1x/week), as is commonly advised for organically managed turfs. It takes 2-3 days for the white flowers to develop, so that they are present for only about half of the total period in which they are flowering. At the Oaks, most heavy flowering occurred from the second half of June through to early August.

The unsightly patch problem (as on the F field) results from clonal growth of clover from isolated individual clover plants. When the clover is well dispersed, as on the B field at The Oaks, it does not have the unsightly appearance. Other factors contributing to a better blending of the clover was the abundance of perennial ryegrass which seems to blend better with the clover than Kentucky bluegrass, and the fact that the B field did not go into mid-summer dormancy, perhaps due in large part to the abundance of clover itself.

Studies of pasture flora have shown that clover exhibits a positive association with perennial ryegrass, i.e. clover tends to be found more commonly with perennial ryegrass, than with other grass species in pastures (Turkington and Burdon, 1983). One factor responsible is the complementary seasonal cycles of growth, the perennial ryegrass growing most strongly in spring and late summer/early fall, and the clover in mid-summer. Turkington and Harper (1979) describe a "regeneration cycle" in permanent pastures, in which clover invades when soil N levels fall. Perennial ryegrass "tracks" the clover, invading the clover dominated sward after the N has built up. After perennial ryegrass reaches a peak, other, taller growing grasses invade the sward, particularly if grazing is weak, and these are replaced in turn by slower growing, less demanding grasses as the N level falls. Finally clover responds to the lower N levels, re-establishes, and cycle is repeated. Very similar cycles appear to occur in turfs that receive little or modest levels of fertilizer-N. There is a self regulation that puts N into the system when it is needed via clover, and exploits it when it builds up via grasses. Because these interactions closely couple supply and demand for N, the level of free N in the soil solution will remain low, which minimizes leaching of nitrate and cations, while maintaining adequate N nutrition.

The benefits of clover not withstanding, it may still be desirable or be the preference of the consumer, not to include clover, or to keep it at relatively low abundance. ***The observations on clover in different treatments illustrated marked effects of fertility management on clover abundance. The most critical factor, we deduced in Section III.1C, was maintenance of moderate levels of inorganic N through the establishment year.*** On the F field, growth and number of clonal patches increased rapidly between 1993 and 1994; gain in verdure was restricted in 1993 in comparison to the B field; that combined with low N on most plots, allowed clover to increase rapidly. Had we wanted to maintain the site clover-free, it likely would have been possible had we started regular weeding of clover in 1993, but by 1994, it was too late.

Based on observations at The Oaks, and others in the literature, we offer a ***provisional strategy for managing clover in organic turf systems***. It is presented in the form of a dichotomous set of conditions and options for dealing with them.

1a Established turf, clover present at high levels

-*Encourage clover* by mowing short in the spring (3-5 cm) and by not applying more than 1/4 lb N per 1000 sq ft in early spring.

-*Discourage clover* by mowing at 7.5 cm height or the highest mower setting, and apply organofertilizer at 1 lb per 1000 sq ft in early spring.

1b Established turf, clover not present

-*Encourage clover* by overseeding, mowing short, and applying only low amounts of N in the spring. Frost seeding is a good way to get the clover in early and to its advantage. Frost seeding is a method of seeding when ground alternately freezes and thaws on the surface in early spring which opens up natural fissures for the seeds.

-*Keep clover out* by manual removal of any clover, inspecting turf at 1-2 month intervals.

2a New turf (established on renovated soil, or on new soil with clover in the seedbank

-*Encourage clover* by not fertilizing with more than 1 lb N incorporated in the soil, and applying no top dressings until fall dormant feed.

-*Discourage clover* by ensuring maintenance of moderate nitrate-N levels in the soil by incorporating a slow release N source such as brewery waste, and/or frequent applications of organofertilizer (2 lbs N incorporated late May; 1/2 lb top dressed at three week intervals until fall).

2b New turf, clover not in seed bank

-*Encourage clover* by seeding Dutch white clover at 3-6 lbs/acre (0.07-0.13 lbs or 32-60 g per 1000 sq ft) or overseeding in the first fall or the following spring; use modest N first year (2 lbs maximum).

-*Discourage clover* by monitoring[2] and removal at 1-2 month intervals.

Particular attention should be paid to adequacy of P, K, Mg, Ca, and S for clover (Turkington and Burdon, 1983). There was some indication that the F field was at times deficient or close to deficient in S, Mo, and Mg, which could have been a factor in clover not persisting well on that field.

Top-dressing of organofertilizers

There are several key considerations or questions that arise in regard to use of organofertilizers on turf.

Provision of macronutrients other than N, and problems of balance

With synthetic fertilizers, it is relatively simple to apply specific amounts of each of N, P, and K. This is more difficult under organic management because of limited availability of materials that are high in one element but low in the others. Suppliers of organic fertilizers are beginning to make blends available with a wider range of NPK ratios, however, if one wishes to make use of what is most readily available (and usually most affordable), then the options are still very limited.

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[2] Presence of clover in the seedbank can be tested by simple tray techniques; soil collected in the fall should be vernalized for 1 month first (Hill et al., 1989).

Under organic management, the key to minimizing imbalance problems is to manage the system to minimize the need for N. Then, even when materials with near equivalent N-P-K are used, there is much less likelihood of serious imbalances being created due to more P and K being applied relative to N than need be. On the other hand, the minimal use of N will also tend to reduce losses of K, Mg and Ca by leaching, so that lower than conventional rates of application should be possible for maintenance of these nutrients. ***Suggested default values (values suggested in the absence of soil tests or budgets) for P and K are 1/6 and 1/2 of the amount of N as P_2O_5 and K_2O respectively.*** For example, if the suggested application for N (discussed below) is 2 lbs per 1000 sq ft per annum, the suggested application of K_20 is 1 lb and for P_2O_5, 0.3 lb. If substantially less than those amounts are being applied with the organofertilizer being used as a source of N, then over time, reservoirs could decline; if substantially more, then over time, excessive levels might build up. When soil tests are made, the comments made about reservoirs under "soil audits" above, should be taken into account.

Minimizing needs for nitrogen

The major factors involved in minimizing needs for N are:

(1) recycling within the system (mulch mowing in the case of turfs);

(2) maintaining cover and root density to minimize losses by erosion and leaching,

(3) inclusion of N_2 -fixing plants,

(4) handling supplements in such a way that minimizes the possibility for a surge in the nitrate pool in the soil (surges can result in loses of N by leaching and denitrification accompanied by acidification of soil and loss of cations), and,

(5) taking into account differences in supply of N from the soil and in the accumulation of N in soil as soil organic matter.

In an organically managed turf in which clippings are recycled, and clover is a component, the first three conditions are met quite well. What becomes very important is to avoid increasing nitrate to levels that would result in significant loss by leaching, or denitrification.

Thus a critical issue is to identify real N requirements. In a turf system in which clippings are recycled, the need for N supplements are potentially, very low. ***In principle, turf has amongst the highest potential of all agricultural and horticultural crops to maintain high quality with very low nutrient supplementation as it is a perennial crop in which there is no product that must be taken out of the system.*** In practice, however, "high end" turf is one of the most heavily fertilized systems, receiving 150-250 (3-5 lbs N per 1000 sq ft equivalent) or more annually. These application rates are well in excess of typical applications to grain crops in Nova Scotia (circa 100 kg N per ha) and to hay (circa 75 kg), and approach those for intensive, very high yield systems such as ICM (Intensive Cereal Management) wheat. Inputs on golf courses equal or exceed those in the most intensive agricultural systems (Dynisveld 1992).

The most closely analogous agricultural model for organically managed turf is Voisin Grazing Management, which is a system of rotational livestock grazing of grass/white clover mixes. Such systems can operate productively with little or no use of N supplements (Murphy, et.al., 1986, Murphy, 1994). One reason for the competitiveness of livestock production in New Zealand is that they have developed a system for managing productive pastures that utilizes clover and grazing management to provide virtually all of the N (Floate, 1987). There is no biological reason why the same is not possible with turfs, substituting "high quality turf" for "productive pastures" and "lawnmowers" for "grazers". The only inherent restriction may be that a small N supplement is required in late fall to ensure early spring greening, and even that may be unnecessary in many cases.

Without clover in the system, there will be a net requirement for N to make up for losses, however for a recycling, sod type system not receiving large N supplements, such losses should be very low. Plant uptake systems are saturated at very low concentrations of soil solution nitrate and ammonium (<1 ppm N). Thus, providing there is a continuous supply of inorganic N by continuous mineralization of organic materials, the grass will have adequate N even though there is never a large amount in the soil solution. As the level of nitrate ($NO3^-$) in the soil solution decreases, so does the content of the counterions K^+, Mg^{++} and Ca^{++}, and the electrical conductivity drops accordingly (Patriquin et.al., 1993). Thus by the end of 1994 on both fields, nitrate and electrical conductivity (Figure I3) had dropped to very low values, while productivity had stabilized at high values. Under such conditions, leaching losses of nitrate should be less than 25 kg N per ha, and probably less than 5-10 kg N per ha, i.e. in principle, one would have to only add 5-10 kg supplemental N per ha to maintain the system.

That is the potential. In practice, to maintain high quality turf given less than ideal starting conditions, which can include a high component of Kentucky bluegrass cultivars with high N requirements, low soil organic matter, and possibly reduced root systems, real needs to maintain high quality could be considerably higher. However in a recycling system, they should not at the extreme exceed about 3 lbs of N per annum, appropriately applied. ***If a system has low soil organic matter initially, e.g. 2%, then under an organic regime in which the equilibrium soil organic matter value is in the area of 6%, accumulating soil organic matter will be a sink for some of the added N, possibly as much as 2-3 lbs N per annum. Likewise until the root systems build up, losses may be higher than the values suggested above, and the accumulating roots will sequester some of the added N.***

How important is the soil organic matter factor? As we described above, in separate greenhouse experiments with turf growing in pots in different soils, short term supply of N was strongly correlated with soil organic matter. The two fields at The Oaks fall respectively in the lower 1/3 and upper 1/3 for soil organic matter values observed for the Metro turfs included in that study. Thus the N needs of the two turfs (B low, F high) can be considered to bracket the needs of turf of similar species composition on soils with low to high soil organic matter. Towards the lower end, 3 lbs N are required, and towards the upper, none, or 1/4 pound as dormant feed are required to promote early greening up. (The uncertainty between zero or 1/4 lb relates to the decreasing time interval in which differences in greening up in different fertility treatments were noted in spring on the B field. In 1993, the period of response to organofertilizer extended to early June, in 1994, only to early May. In 1995, the B field turf, not fertilized in fall of 1994, greened up at the same time as the earliest turf on residential properties. Thus, the interval seemed to have dropped to zero.)

We are suggesting then, partly on theoretical grounds, and partly from the documented responses at The Oaks, that ***real N needs for high quality organically managed turfs with mixed grass swards are likely to be in the range of 0-3 lbs N.*** In order to predict real N needs (in lieu of convenient tests for soil N), we offer the following, provisional guidelines based on results at The Oaks and of Vessey and Patriquin (1984) for input of N via clover:

(1) The needs for a mulch mowed turf with a mixed sward will be in the range 1/2 to 3 lbs N.

(2) Requirements will be towards the lower end of this range where soil organic matter is >5%, and towards the higher end where it is <3%, provisionally the following:

Soil Organic Matter (%)	**Organofertilizer-N (lb per 1000 sq ft per annum)**
2-3	3
3-4	2
4-5	1.5
5-6	1-0.5
>6	0.25-0

(3) Bag mowing can be assumed to increase requirements by 1-2 lbs N.

(4) If clover in mid-summer is present at > 50% cover, assume 1.5 lbs of N is added, and proportionally less with proportionally less cover of clover.

(5) For a new turf, established by sod, adding a mature compost to the soil at a rate of 100 t per ha (1 inch) will supply 1.5 or more lbs N the first year, and 1 lb annually for the next two years.

(6) If turf is >40-80% Kentucky bluegrass, increase requirements by 0.5 to 2 lbs. Overseed with perennial ryegrass and fescues to reduce proportion of Kentucky bluegrass.

An example of how this system might be applied is the following:

Given a mulch mowed system with:

Soil organic matter of 4%, needs = 2 lbs N
Kentucky bluegrass at 50%, additional need is 0.5 + 1.5*(50-40)/40 =0.88 lbs N
Clover 25%; contribution is 25/50 x 1.5 = 0.75 lb N
Net requirement: 2+0.88- 0.75 = 2.1 lbs N

W suggest that these provisional values so calculated could be tried with little risk of reducing quality. Lower rates than those might also be tried on small areas, and if those prove to be adequate, the applications for the larger area could be reduced accordingly.

When should applications be made?

In the last 10 years, the turf industry in Canada has been shifting from a heavy early fall feed to a late fall or "dormant" feed. The dormant feed is applied when top growth has ceased but photosynthesis and root uptake are still active. Dormant feed is reported to stimulate photosynthesis and carbohydrate production at temperatures just above freezing with no apparent shoot growth, respiration or carbohydrate utilization and results in maintenance of desirable turf color through the winter and into spring (Turner and Hummel, 1992). It is commonly assumed that a dormant feed would not work with organofertilizers because the temperatures would be too low to allow release of inorganic N. Talbot (1990) advises early fall fertilization for organic turfs. A trial dormant feed in 1992 proved to be highly effective; compared to making the final application in early September, applying organofertilizer on Nov. 6, 1992, resulted in substantially better greening up and earlier onset of growth, and reduced winter injury in 1993. (Figures B3, D1). Analysis of climatic data (Section VII-Appendix 1) suggest that this application had been made 25 days before onset of effective seasonal dormancy. In 1993, all fall applications were made on Nov. 17, which was one month before the time estimated for onset of winter dormancy, and there was excellent greening up in 1994. We did not test later dates of application, but it appears that one month before effective dormancy is a good time; it did not stimulate extra growth, and did effect earlier greening up in the spring. ***We suggest that the dormant feed of N is the most critical application, with up to one l lb of organofertilizer-N being applied approximately one month before onset of effective winter dormancy.*** For Nova Scotia, the timing is likely to be mid-October to mid-November, using a material of 5%N or greater.

Provisional recommendations for annual organofertilizer applications follow (units are lbs N per 1000 sq ft):

Total N applied over the year	Dormant feed	Applied in late May or early June	Applied late June*	Applied late Aug/early Sept.
3	1	1	0.5	0.5
2.5	1	1	0	0.5
2	1	1	0	0
1	0.5	0.5	0	0
0.5	0.25	0.25	0	0
0.25	0.25	0	0	0

* Apply in late June only if turf is being watered in mid-summer to prevent grass going into summer dormancy; there is less danger of burning with organofertilizer than with NPK. NPK applied in mid-summer reduced clipping yields sharply, while organofertilizer increased them (Section III.1A).

Other management factors

Pests and diseases

Insect pests did not become problematical in The Oaks experiments. We had been concerned that chinch bug might become a problem as it had been previously on the B field (Photos 1b). Chinch was observed in 1993 on a droughty corner of the B field but it did not spread into the rest of the field in significant numbers (Photos 10a). We applied dilute soap solution to the entire field in 1993 to set back potential infestation, however, it seems likely that it was the inherent resistance of the system (lack of water stress, low thatch) that limited its spread, rather than the soap solution (see Box 7 for comments on chinch bug in organic systems). Similarly other potential pests were observed in low numbers and did not have noticeably deleterious effects.

There were, however, several diseases that reached levels resulting in noticeable effects on turf quality. Many turf diseases are affected by N nutrition of the grasses, some being stimulated by excess N and some by N deficiency (Smiley, et.al., 1992). ***Four diseases developed at The Oaks: red thread (Photo 11a), anthracnose (Photos 12 a,b), leaf spot (Dreschlera spp and Septoria spp) (Photos 11b,c) and pink snow mold (Photos 14 a,b). The first three were observed initially only on Kentucky bluegrass. Pink snow mold occurred primarily on tall fescues.*** Two of the diseases on Kentucky bluegrass - red thread and anthracnose - are diseases commonly associated with low N, and they exhibited patterns of occurrence, between fertility treatments in their first year of (noticeable) occurrence that are consistent with that description. The two leaf spot diseases are not described as being sensitive to N. There were no diseases of excess N. As discussed above, N stress of Kentucky bluegrass may have been a critical factor in the initial establishment of red thread and anthracnose in the turfs.

Red thread was first observed in 1993. Serious infestation was restricted to the F field (Figure F1), and occurred largely on Kentucky bluegrass and on the lower fertility plots. In 1994, it occurred on both fields, on other species, and even on Control main plots receiving high levels of organofertilizer. Its etiology had changed, presumably due to the buildup of a very high innoculum on stressed plots in 1993. Anthracnose was not observed to spread significantly to other species in 1995, and remained at about the levels it had occurred in 1994. This shift in the etiology of the red thread allowed us to document changes in factors affecting its abundance in the two phases, and suggests a strategy for preventing infestation or dealing with infestations of the diseases associated with N deficiency:

Provisional strategy for control of diseases associated with N deficiency :

To maximize resistance to initial infestation:

(1) Ensure the presence of grass species and cultivars that are not strongly N stressed at moderate levels of N.

(2) Ensure that grass species receive adequate but not excessive N; the level of augmentation required will increase with the proportion of Kentucky bluegrass in the turf.

(3) Incorporate (new turf) or top-dress (established turf) with compost. Compost appears to have suppressive effects that are independent of N supply (Section III.1F; Lumsden et.al. (1983)).

(4) Include clover in the system. It improves N nutrition of associated grasses and provides a natural regulation of N that minimizes likelihood of N deficiencies.

(5) Mulch mow. This reduces water stress and improves N nutrition.

Control established infestations by:

(1) Raking infected areas to remove debris, followed by (2).

(2) Application of dilute soap solution to set back active inoculum remaining, followed by (3).

(3) Application of organofertilizer at 1/2 - 1 lbs N per 1000 sq ft.

(4) Bag mowing until the conditions appears well under control.

If available, liquid fish silage might be used in place of steps (2) and (3).

At The Oaks, red thread developed again in 1995. Then the entire F field received organofertilizer-N. This appeared to have brought the whole system under adequate control, and in the fall of 1995, there was not the reoccurrence of heavy infestation on either field that we observed in 1993 and 1994. ***Thus we conclude, provisionally, that these diseases do not have to be serious problems in organically managed systems***. As in IPM, prediction of susceptible phases based on weather, monitoring pests and diseases, and understanding their etiology are important.

Mowing

Changing from mulch mowing to bag mowing on certain subplots on July 17, 1993 resulted in reduced verdure (Figure A5), clipping yield (Figure A6) and increased disease (Figures F4, F5) in 1994, even at the higher levels of fertilization. Bag mowing increases N needs by 1-2 lbs, and removes large amounts of other nutrients (Table H3). ***Thus mulch mowing must be considered an essential component of organic management; however, bag mowing is appropriate when diseases build up.*** The standard mowing practice at The Oaks was to mow high (2.5 inches) and frequently (once weekly for most of the season), and to reduce the height in several steps in the fall. Mulch mowing is commonly advocated for organic management as a means to reduce stress and increase competitiveness with weeds.

It is probable that lower mowing heights could be tolerated without increasing stress or weediness in turfs with a lot of clover. Lowering the mowing height would probably increase the abundance of clover (Photo 7c).

Weeds

Weed control is regarded as the Achilles heel of organic turf management. These experiments were not designed to address factors affecting weed pressure, as we controlled weeds by manual weeding. Interrupting weeding for the first six months in the 1994 season allowed the weed pressure to be expressed, and we observed significant differences between the different fertility treatments, and between blocks that suggested overall lower weed pressure under the higher fertility regimes.

In the establishment year, a lot of manual weeding followed by overseeding was required in the first month. The weeds were mostly summer annuals (Photo 9a). This requirement could have been greatly reduced had the old turf been rotovated in mid-summer, and harrowed one or two times followed by seeding in early September. Allowing a fallow and harrowing would reduce the number of summer annuals greatly, and those that germinated with the grass, if not weeded, would be winterkilled in an early stage.

Subsequently, ***manual weeding focused primarily on dandelion, violets, and plantains; time requirements were not large (Table C5), and overall weed cover was less than 2%. Optimal timing of weed removal was very important***, which was well illustrated by a sharp increase in the problem weeds in 1995 when weeding was interrupted until the fall of the year (Table C2). Those data illustrate a strong fertility effect on weeds, and by inference, of clover.

It has been established as a valid generalization for herbaceous communities in temperate regions, that diversity of herbaceous vegetation increases with increasing site fertility to a maximum value and then declines with further increase (Marrs, 1993). The more fertile turfs lies towards the upper part of this curve, with low species diversity, and the infertile turfs, in the region of maximum diversity - thus differences in fertility can have a very strong impact on the natural diversity or weediness of turfs.

In conclusion, the following strategies for managing weeds under organic management are suggested:

(1) As possible, when new topsoil is introduced, conduct some weed germination tests on the soil before hand to determine weed potential.

(2) If the seedbank is large, then before seeding new turf, plan for a fallow period with time for at least one harrowing to reduce weeds in the seedbed.

(3) Manual weed systematically in late spring and late summer.

(4) Where larger gaps are created from weed removal, overseed with at least 50% perennial ryegrass, and introduce other species as desired. Mulch with compost or mineral soil.

(5) Focus on problem and controllable weeds, particularly the broadleaf varieties.

(6) If plantain is not present initially, it can be kept out by practicing vigilance in removing new plantain plants; seeds do not disperse far from parent plants, but seedbanks are persistent and once established, create a recurring weed problem.

(7) Dandelion produces light seed that is widely dispersed, but is non persistent, thus it can repeatedly invade in large numbers from outside sources. Removing dandelion in adjacent areas can reduce that; plan to remove seedlings a few weeks after the major seed rains in late spring.

(8) Certain weeds if abundant, may indicate soil imbalances or physical problems (Hill and Ramsey, 1977; Walters and Fenzau, 1979; Patriquin, 1988).

(9) A major benefit of clover is that it competes effectively with broad leaf weeds; including clover in the system and managing it appropriately will greatly reduce manual weeding requirements in the long run.

(10) Mow high and frequently; with clover, lower mowing height can be tolerated, but increases the clover component.

(11) Maintain adequate but not excessive fertility, and other conditions favoring a strong grass sward.

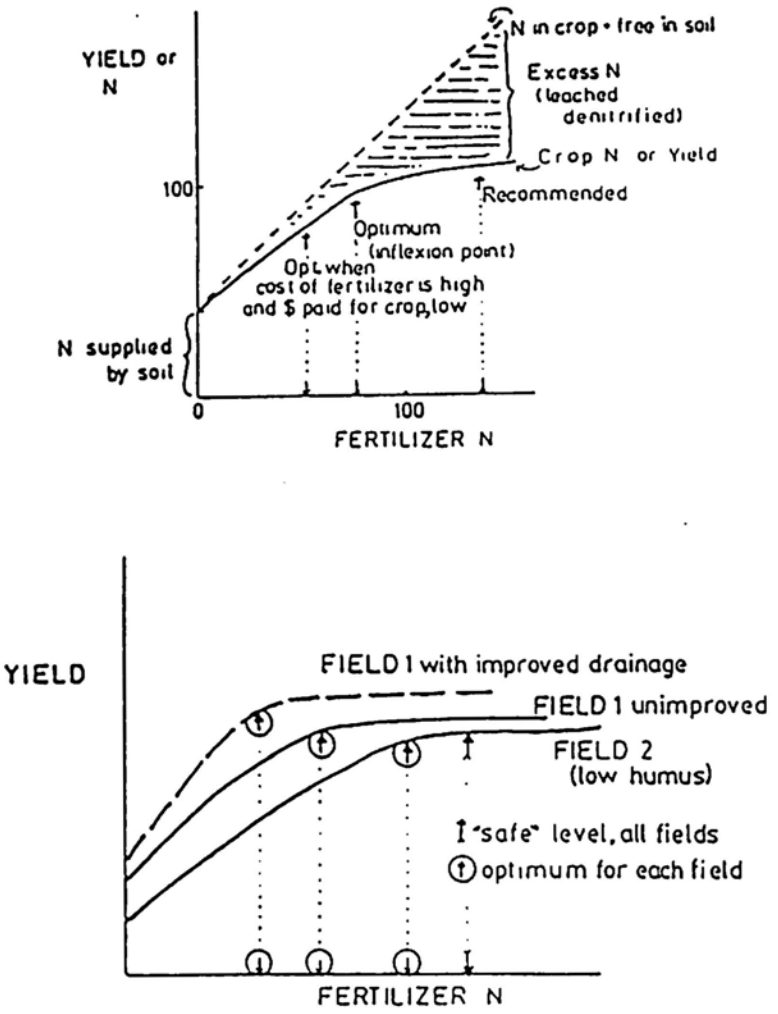

Figure IV.1. Top: typical relationship between yield (or crop N or crop N + soluble N in soil), and amount of N fertilizer applied. Bottom: hypothetical relationship between yield and amount of N fertilizer applied in three situations on the same farm (from Patriquin, 1989).

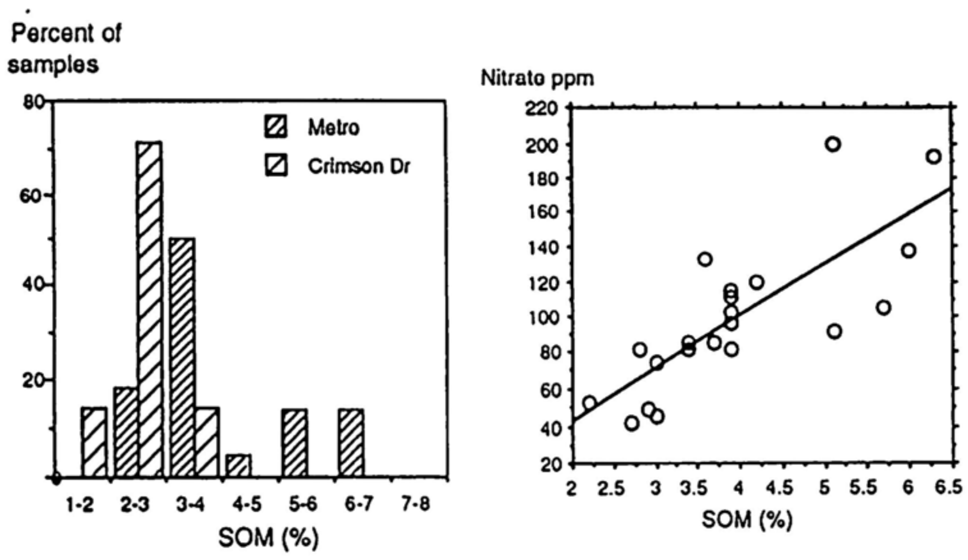

Figure IV.2. A. Soil organic matter for Metro turfs and for Crimson Drive (a new development). B. Relationship of nitrate production by Metro soils incubated for 28 days at 22 °C and soil organic matter ($r^2 = 0.603$). For Metro soils, n = 22; soils were taken from commercial, institutional, and residential properties serviced by Edmonds (M. Hope-Simpson and D. Patriquin, unpublished). For Crimson Drive, n = 28 (Loucks, et.al., 1994).

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PHOTO 1: **Establishment year.**

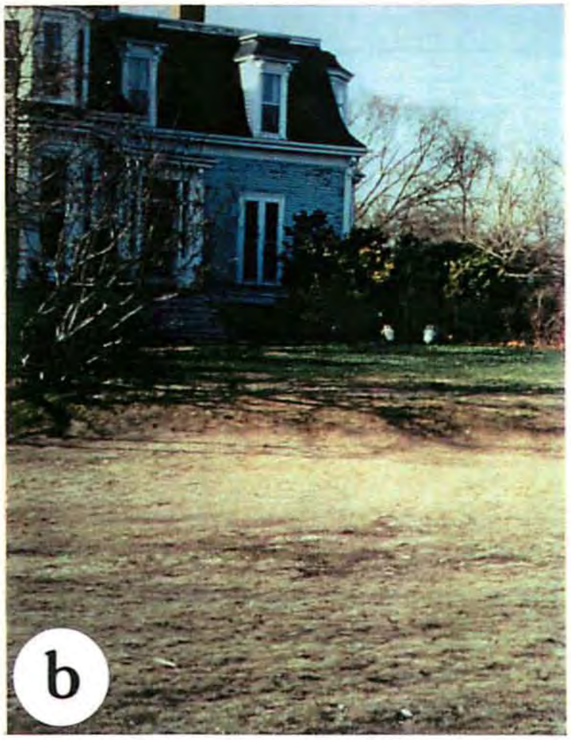
a. Spent grain being distributed on a Brewery Waste main plot; subsequently it was incorporated by rotovating.

b. In the foreground, the experimental turf before renovation in April, 1992. Turf had been totally destroyed by chinch bug.

c. Same turf in September, 1992.

d. Control (foreground), Brewery Waste and Compost main plots in Block 1, after spreading brewery waste and compost.


a


b


d


c

PHOTO 2: **Winter injury.**

a. Compost main plot, Block 2 on April 26, 1993. Plot in foreground that had received a dormant feed of organofertilizer in 1992 exhibited the least winter injury. The other plot outlined by a quadrat received no organofertilizer.

b. The same area on April 25, 1995, showing early spring greening and absence of winter injury.

c. Single species plot of Reliant hard fescue, June 27, 1993. It suffered the most winter injury of all single species plots. Clover and weeds filled in the spaces created by winter kill of grass.


a


b


RELIANT
(Hard fescue)
c

PHOTO 3: Winter injury in monospecfic demonstation and organofertilizer plots.

Photos taken on May 17, 1993; the white margins are the inner edges of 25 x 25 cm quadrats. Plots from top to bottom are:

- **a.** F field; Cn2D (dormant feed)
- **b.** Haga
- **c.** Fortress
- **d.** Clover
- **e.** F field; Cn0
- **f.** Palmer
- **g.** Reliant
- **h.** Tall fescue

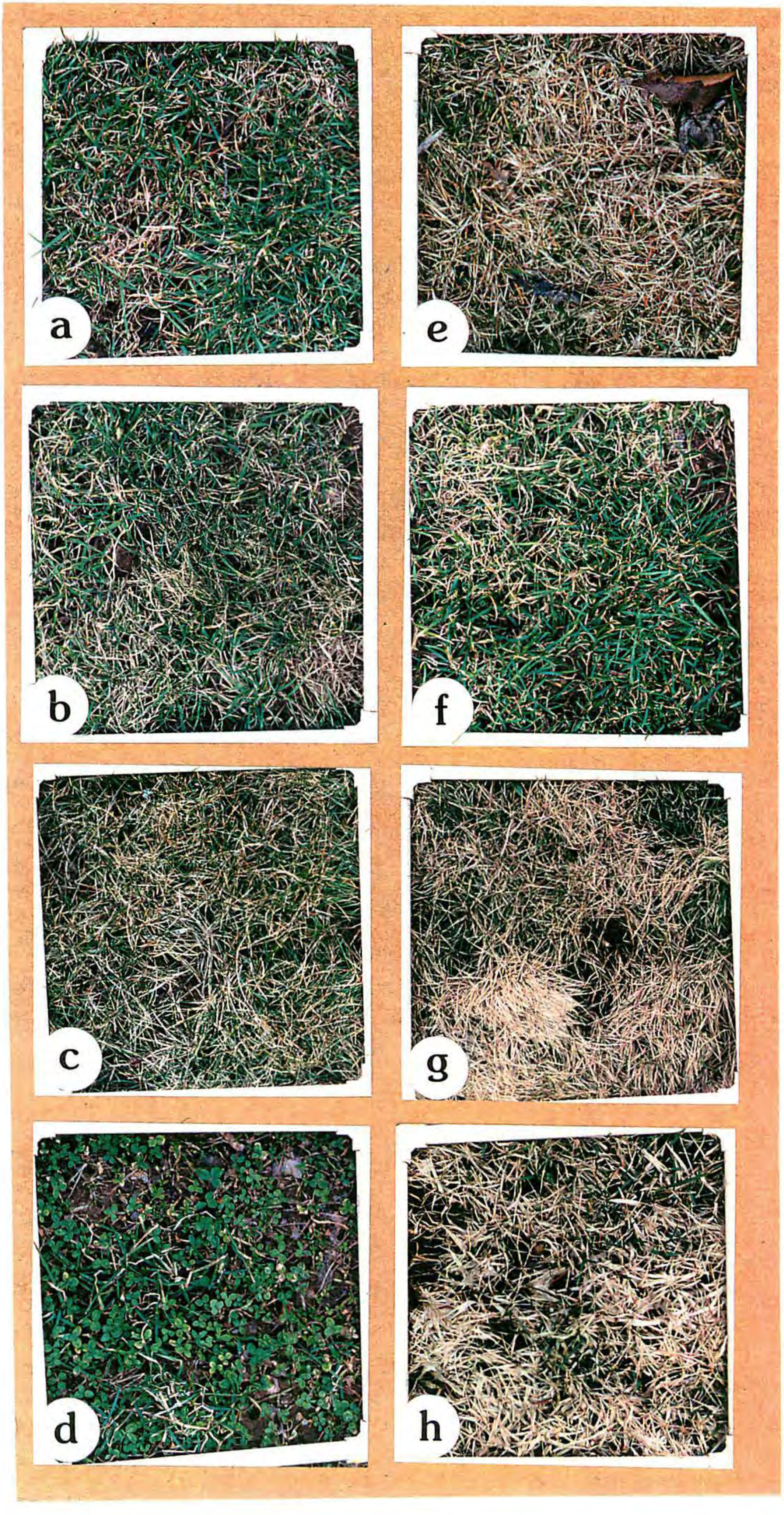

a
e
b
f
c
g
d
h

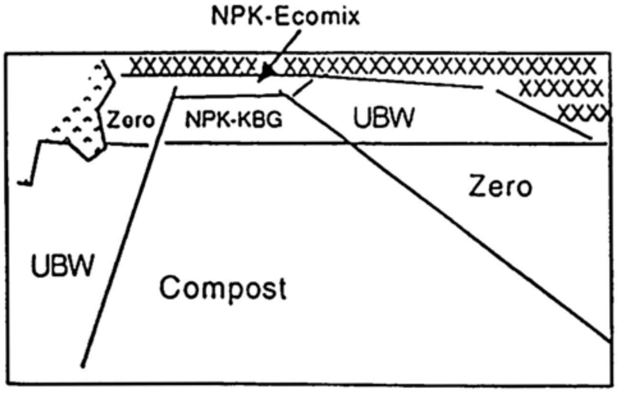
PHOTO 4: Greenness of commerical properties and at The Oaks (1992).

a. Commercial property in full sun maintained with Seagreen organofertilizer at 3 lbs N per 1000 sq ft per annum.

b. Residential property in the shade, maintained with Seagreen organofertilizer at 3 lbs N per 1000 sq ft per annum.

c. Trial on a commercial property, August 13, 1991; in foreground, no fertilizer, in background, Seagreen organofertilizer applied at 3 lbs N per 1000 sq ft on May 29. Organofertilizer treated plots were more drought resistant.

d. Plots at The Oaks on August 15, 1992. The figure below identifies the different main plots in the photo. Note the Compost plot and the NPK-Kentucky bluegrass plots are lighter green than the Control main plot, and the Brewery Waste main plots are darkest green. The main plots are readily distinguishable, but the subplots are not.




a


b


c

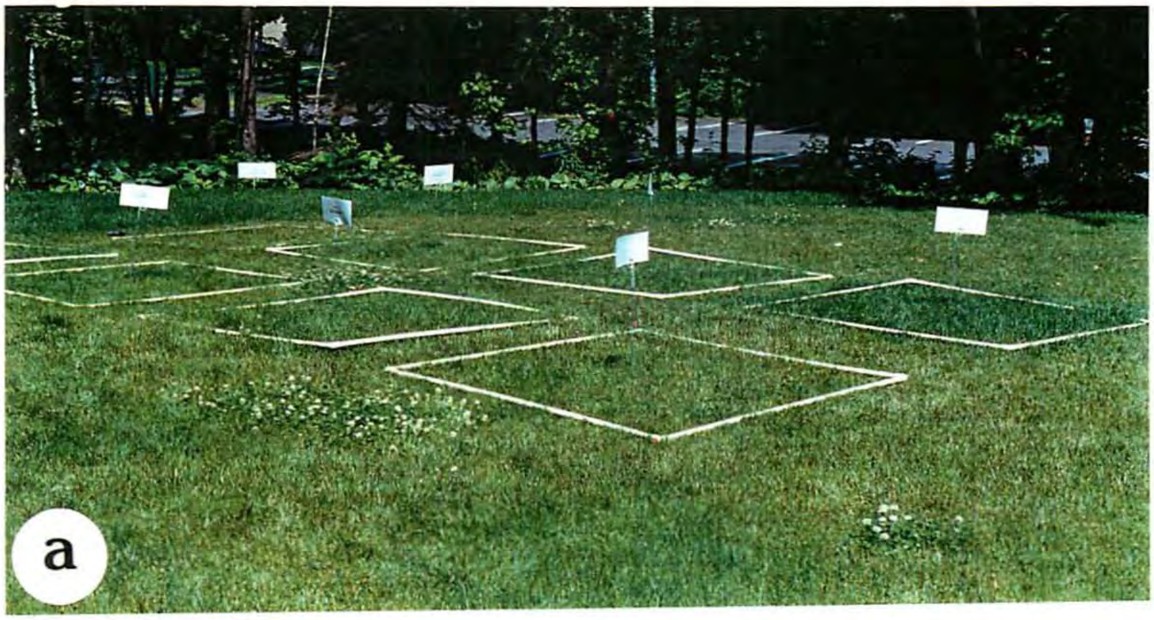

d

PHOTO 5: **Greenness of The Oaks, 1993.**

a. Organofertilizer subplots on the Control main plot, F field, June 27. Note the strong response to organofertilizer. Plot at top right received the highest level of organofertilizer (3 lbs N per 1000 sq ft per annum); plot at bottom right received none. Note also the small patches of clover. Dark green grass in the background is the Mixtures experiment, Replicate 3, established on compost and receiving 3 lbs organofertilizer-N per season.

b. Block 1 on the B field, June 27. Organofertilizer plots did not stand out here.

c. F field, June 27. Grass behind the fence is Ecomix established on compost + brewery waste amended soil and top-dressed with 3 lbs organofertilizer-N per season.


a


b


c

PHOTO 6: Greenness of The Oaks, 1994.

a. Subplots on Control main plot, F field, July 14. Plots, proceeding from background to foreground are:

OF1 (mulch)	OF1 (bag)
OF2	OF3
OF0	OF3X

Note severe water stress and red thread in much of the area, also large clover patches compared to those in Photo 4a.

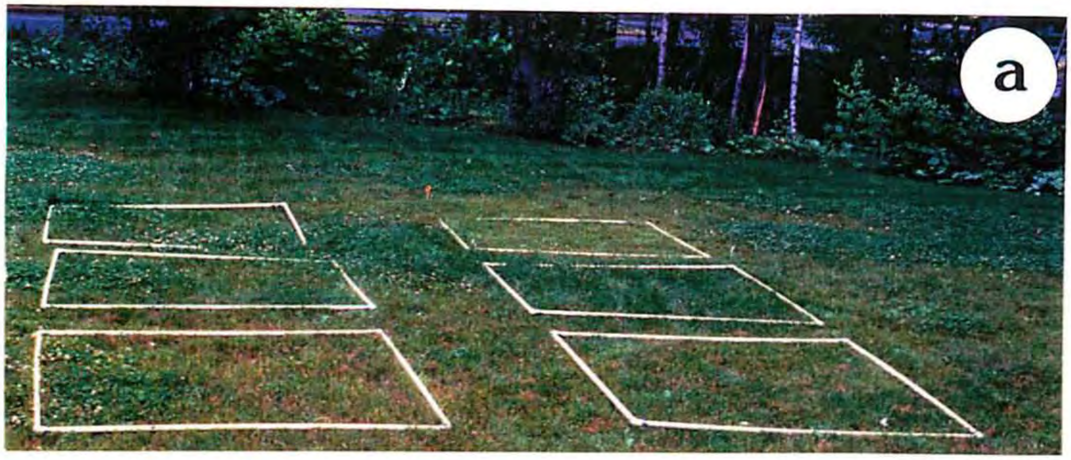
b. Subplots on the Control main plot, Block 1, B field, July 14. Plots, proceeding from background to foreground are:

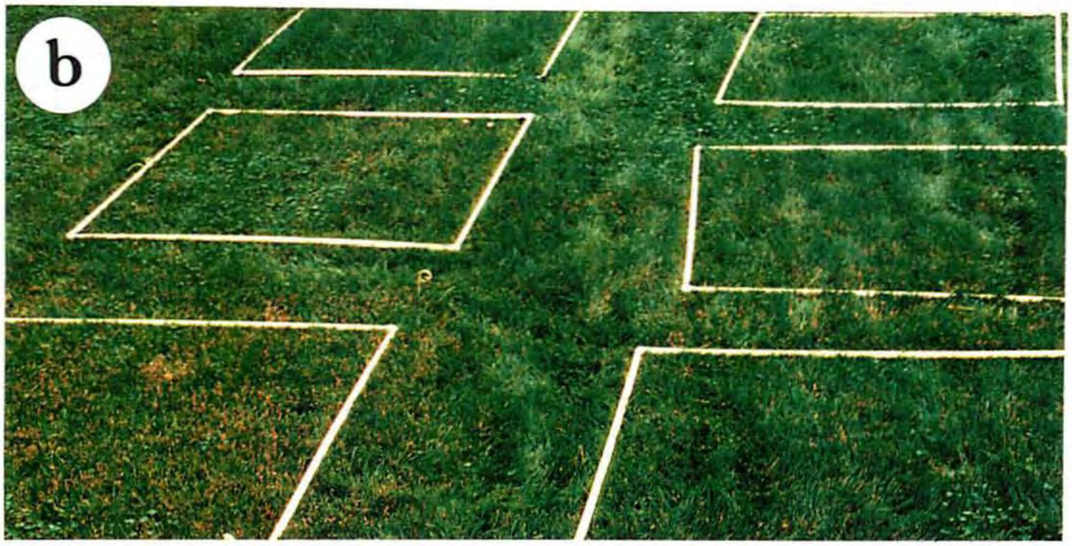
OF3	OF2
OF0	OF1 (mulch)
OF1 (bag)	OF2

Note prominence of anthracnose in OF1 bag mowed plot.

c. F field, December 6, 1994. Light colored areas in mid right and background of photo are tall fescue plots. Those in the foreground are two plots side by side, one with Rebel and one with the Tribute cultivar, established on compost + brewery waste plus annual top-dressings of organofertilizer. The strip in the background is plus clover tall fescue mixture plot. To the left in background is the Control main plot- note that is is uniformly dark green, in marked contrast to the condition in mid-summer (above).

d. View looking across Compost main plot, Block 2 on the B field into Block 1, Dec. 6, 1994. Note contrast between Compost Block 2 foreground and background (Control to the left of background area, Brewery Waste in middle and Compost to far right).


a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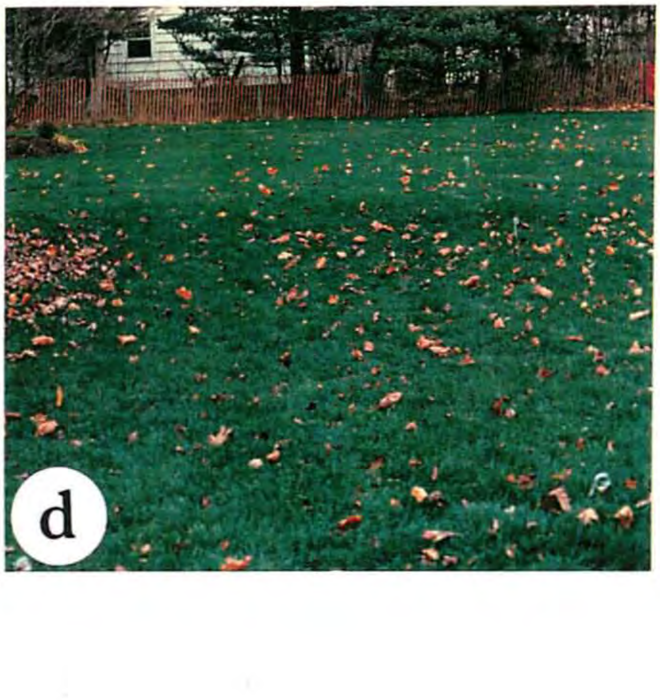
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PHOTO 7: Clover.

a. A clover patch on the F field, July 23, 1993. The patch contrasts sharply with the clover-free area outside of the patch. Frequency of clover within the patch would be 100%, cover approximately 80%.

b. Diffusely distributed clover on the B field. The quadrat (50 x 50 cm subdivided into 16 squares) was placed on a plus clover region on Cn2 subplot on Block 1, July 14, 1994. Frequency of clover cover is 100%, cover is approximately 30%. Note that clover color and density blends more evenly with grass than in Photo 1a.

c. Clover on a residential turf in Halifax, September 5, 1995 (at height of the late summer droughty period). This turf was overseeded with clover 10 years previously. It was fertilized once yearly, with organofertilizers at approximately 1 lb N per 1000 sq ft in spring, until 1993, when that was changed to a dormant feed. Grass is mowed approximately weekly to 2 inches height. Note high cover by clover, the blending of clover-dominated and grass-dominated patches, and maintenance of consistent greenness of the whole sward during a late summer drought.


a


b


c

PHOTO 8: **Clover: nodulation and N stress, July 23, 1993.**

a. Roots of clover from light green (N stressed) clover plants. Note many nodules along length of the roots.

b. Roots of clover from dark green clover plants. There are a few, large nodules on the distal younger parts of the roots. There are no nodules on the upper, older parts of the roots.

c. Clover on the Compost main plot, Block 2 of B field, outside of subplots (no organofertilizer). Note the dark clover at left and light clover at right.


a


b


c

PHOTO 9: **Weeds.**

a. Dense witch grass in Ecomix on the B field in July, 1992.

b. Weeds typical of the B field in early June, 1992 - blackberry, violets, and witch grass.

c. Lambsquarter and grass seedlings on the F field in early June, 1992.

d. Overseeding in a patch where grass did not germinate and weeds predominately initially, late June, 1992.

e. *Agrostis* spp. patches in NPK-Kentucky bluegrass plot, October 5, 1993.


a


d


b


c


Main Plot
NPK-Kentucky
Bluegrass
e

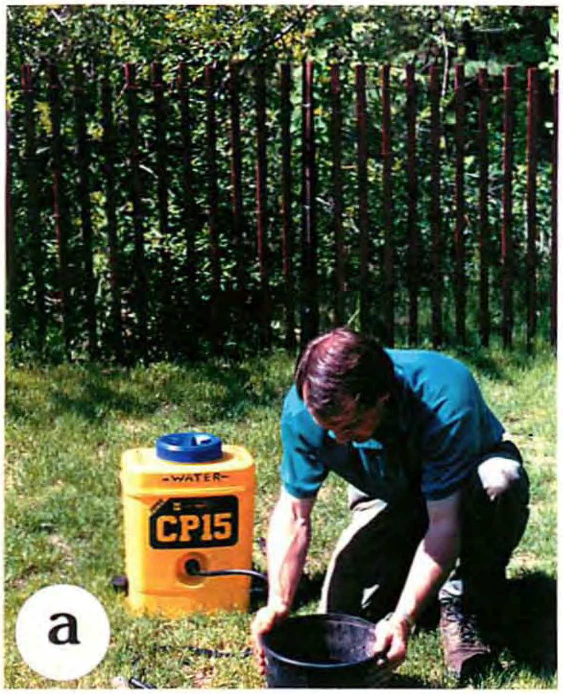
PHOTO 10: **Pests and stressed areas.**

a. Sampling for chinch bug at a chronically stressed area at southwest corner of the B field. Chinch bug was observed in significant numbers in this area.

b. This turf beside the residence at The Oaks, photographed April 26, 1993, had been about 50% destroyed by chinch bug, prior to implementing renovation measures in 1992. Those included soap treatment, diatomaceous earth, dethatching and aeration.

c. The chronically stressed area before it was rototilled in late July, 1993. Organofertilizer was added at 3 lbs N per 1000 sq ft and different grass mixtures were seeded into rototilled soils in late August.

d. The same area, October 5, 1993. There was only a transient improvement in turf quality, regardless of the mixture.


-WATER-
CP15
a


b


c

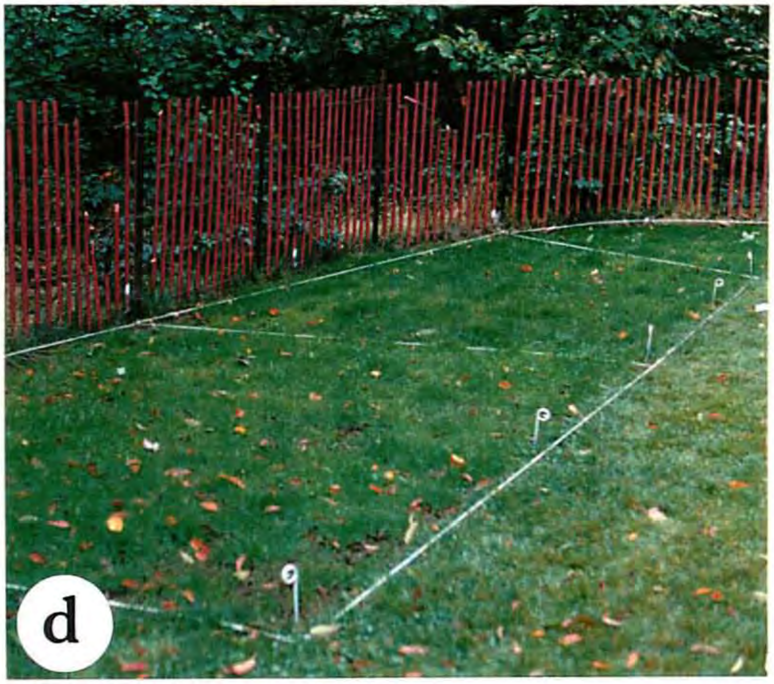

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PHOTO 11: Diseases.

a. Patches of red thread on the F field, July 1993.

b.,c. Leaf spot (probably *Drechslera* spp) on Kentucky bluegrass, May 1993.

d. Diseases on clover. Photo illustrates the three categories we used in decribing patterns of fungal infection on clover: "spots" (distinct black spots on leaf at left margin of photo), "blotches" and "whole leaf necrosis"


a


b


c


d

PHOTO 12: Diseases and thatch.

a. The site with highest anthracnose in July 1993 (part of the Control main plot, Block 1).

b. Closeup of anthracnose on blades of Kentucky bluegrass.

c. Micrographs of a resting spore (RSP) of a parasitic fungus, *Polymyxa graminis* , found in abundance in roots of Kentucky bluegrass at The Oaks (Grandy, 1994). The fungus was identified by Dr. B. Gray, Nova Scotia Agricultural College, Truro, N.S. It has not been reported on *Poa pratenis* before - in fact, *P.pratensis* has been included in lists of species not infected with the fungus.

d. Core illustrating thatch layer at 0 to 1 cm.


a


MM
CM
1
2
3
4
d


b

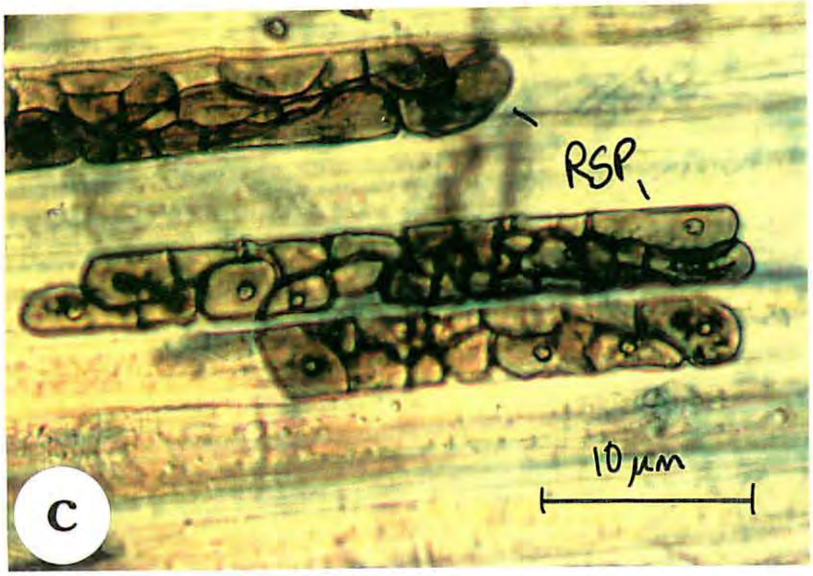

RSP
10 µm
c

PHOTO 13: **Diseases and reddening of Kentucky bluegrass.**

a, b. Leaf spot (*Septoria* spp.) on Kentucky bluegrass in late fall of 1994.

c. Block 1, CnOF1 bag mowed plot with abundant *Septoria* leaf spot, October 5, 1993.

d. Blades of Kentucky bluegrass in NPK-Kentucky bluegrass plots in April, 1995 showing peculiar reddening of leaves with some distal necrosis.


a


b


c


d

PHOTO 14: **Diseases and other conditions on tall fescues.**

a. Pink snow mold on tall fescues in mid-April, 1994.

b. Two side by side plots of tall fescues (one Rebel Jr. and one Tribute) stand out because of intensity of pink snow mold and bleaching of leaves.

c, d. "Bleached" leaves of tall fescues on December 6, 1994. There appeared to be fungal infections on some of the leaves, however, no fungi grew up from the leaves at right, tested by plant pathologists at the N.S. Dept. of Agriculture and Marketing.


a


b


c


d
110
100
90
80
70
60

PLATE 15: **Mixes.**

Photos were taken in Block 1 on July 15, 1994. There is some anthracnose on Kentucky bluegrass in Photos a,c,d.

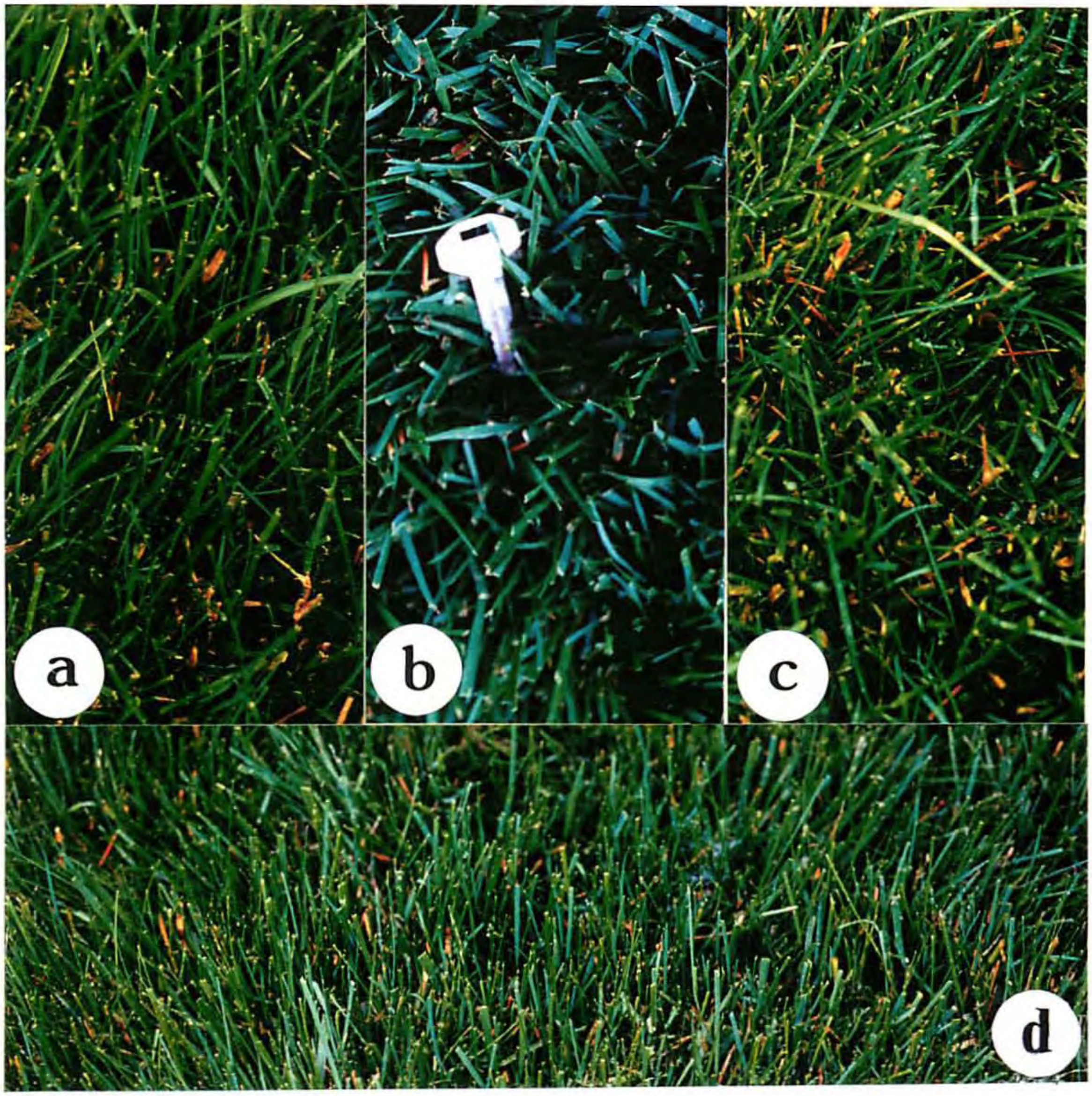
a. Ecomix.

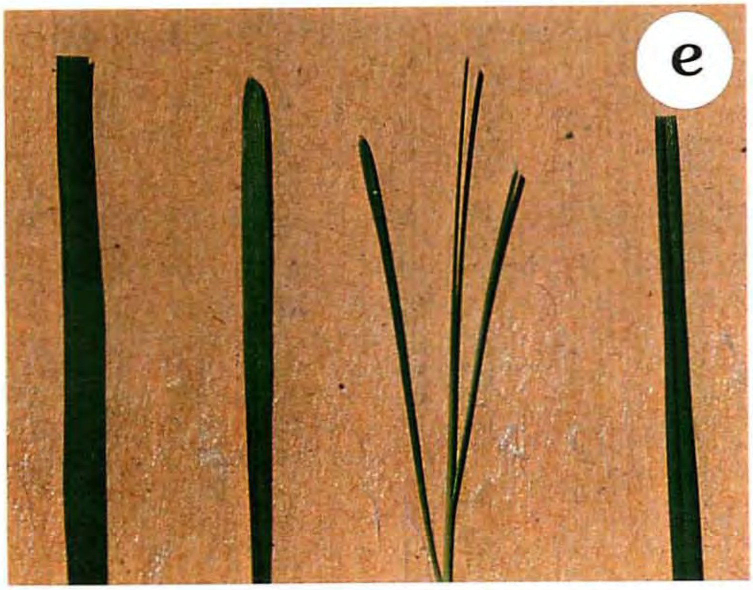
b. Tall fescues.

c. Greenfast.

d. Greenfast + 35% tall fescues.

e. Individual blades of tall fescue, Kentucky bluegrass, a fine fescue, and perennial ryegrass.


a
b
c
d


e

VII. APPENDICES

Appendix 1. The significance of meteorological data in reference to certain observations at The Oaks.

Many of the observations documented at The Oaks were likely influenced by climatological factors. The purpose of this appendix is to graphically present important climatic data over the three years of the project (1992, 1993, 1994), to highlight significant features of the climatic patterns, and to consider how they might have influenced biological phenomena observed at The Oaks.

Predicting the onset of effective seasonal dormancy

For the purposes of this section, "effective seasonal dormancy" is defined to occur when the combination of both chilling and freezing stresses on the turf have slowed or stopped all top growth of the plants and regular cutting has ceased for the season, but photosynthesis and root uptake are still functioning. According to Turner and Hummel (1992), this occurs at temperatures close to freezing. Based upon soil and air temperature data relationships found in Brady, (1974), and Vessey and Patriquin (1984), we are assuming that effective dormancy occurs when mean air temperatures approach 0 °C and are in steady decline, placing mean soil temperatures around 2 - 4 °C but also in steady decline. The dates so inferred for onset of effective seasonal dormancy are given below.

Year	Onset of Effective Seasonal Dormancy	Date Dormant Fertilizer Applied
1992	December 1-2	November 6
1993	December 18-19	November 17
1994	November 27-28	Not Applied

Predicting the onset of spring initialization

For the purposes of this section, "spring initialization" is defined as occurring when steady seasonal warming results in obvious increased greening of the turf, quickly followed by the initiation of active top growth. Based on our seasonal observations in the field and the pertinent climatic data, we estimate that spring initialization occurred when mean air temperatures were approximately 4 °C and steadily warming which implies mean soil temperatures of approximately 6 °C and steadily increasing as well (Vessey and Patriquin, 1984).

Year	Onset of Spring Initialization	Date Spring Fertilizer Applied
1992	Renovation	N/A - Seedling stage
1993	April 13-14	May 18
1994	April 3-4	June 3

Winter injury

Following the establishment year in 1992, a lot of winter injury was documented at The Oaks in the spring of 1993. Meteorological factors that would have favored high winter injury include:

(1) early seasonal dormancy (December 1-2),
(2) severe winter temperatures in January and February of 1993 as indicated in the table below (also see Figure 1.6), and,

Month (1993)	Daily Minimum	60 Year Norm	Difference
January	-10.7	-8.5	-2.2
February	-13.2	-8.3	-4.9

(3) low snow cover for a six week period (December 16, 1992 - January 28, 1993), giving severe and prolonged exposure. The average snow depth in centimeters over the six week period was 0.98 cm (see Figures 1.20 and 1.21).

Diseases

Red thread

This was the most serious disease to develop at The Oaks. Red thread is typically present in the spring and fall on slow growing, N-deficient turf, however, it can occur year round. A spring infection can increase into early summer, suffer a set back in mid-summer, and can increase again in the fall. This typical pattern of infection (Smiley, et.al. 1992) was documented at The Oaks. The disease was first observed in July of 1993 and showed high levels in early August (see Figure F1) on the F-field. The infection retreated considerably in the early fall, and began to proliferate again into the late fall of 1993. Climatic conditions that favor red thread (Smiley, et.al. 1992) include:

(1) prolonged periods of cooling with overcast skies (i.e. poor drying conditions),
(2) moist weather; heavy dews, rain, fog, and,
(3) temperatures in the 5 - 20 °C range.

In the 44 days (June 18 - July 31) leading up to August 1993, at least two of these climatic conditions were present for 23 days. On 10 of the 44 days, all three conditions were present. There was a period of warm (15 °C mean temperature), moist (52 mm total precipitation), and overcast (80.5 hours of bright sunshine) weather from June 18 to June 30 which probably allowed the innoculum to establish. This was followed by a period (July 1 - July 12) of very warm weather (17.8 °C mean temperature) which would have allowed the infection to grow. In the latter part of July, the climatic conditions were perfect for the spread of the disease, especially the last six days (July 26 -31) when the mean temperature was 16.2 °C, the total precipitation was 54.7 mm and the hours of bright sunshine totaled only 14.7 hours.

The set-back of the disease observed in the early fall of 1993, probably resulted from a droughty, warm period from August 4 to September 16 (see Figure 1.17). During this time (44 days), the total precipitation was only 30.3 mm and the maximum daily temperature went above 20 °C on 33 days.

In the latter part of September, conditions again favored the presence and spread of red thread. From September 17 to September 30 (14 days), the mean temperature was 12.9 °C (with no day having a maximum daily temperature over 20 °C), the total precipitation was 91.7 mm, and 9 of the days had less than 5 hours of bright sunshine. October was also a cool (mean temperature of 7.7 °C), wet (192.8 mm of precipitation; 60 year norm = 121.7 mm) month again favoring red thread and likely resulting in the proliferation of the disease in the late fall of 1993, documented on November 17 (see Figure F3).

Pink snow mold

In the spring of 1994, pink snow mold was observed at The Oaks, primarily on the tall fescue plots. Environmental conditions that favour pink snow mold include (Smiley, et.al. 1992):

(1) an optimum temperature range of -1 to 8 °C,
(2) snow cover lasting anywhere from 12 to 90 days, and,
(3) presence of excessive moisture leading to unfrozen soils.

In the 30 days (March 3 - April 2, 1994) leading up to spring initialization (estimated to be April 3-4), meteorological data indicates that at least two of the three environmental factors listed above were present on 20 of the days. In those 30 days, conditions were very wet, (210.5 mm total precipitation; 172.1 mm as rain; 60 year norm for March is 110.8 mm) with the mean temperature being 0.37 °C. There was very little snow cover during this time (snow depth averaged only 1.4 cm). The very wet conditions and cool temperatures were likely prolonged enough to encourage the disease.

Anthracnose

Anthracnose was first observed at The Oaks in July 1994 in localized areas and the disease persisted well into October. Environmental conditions that favour anthracnose include (OMAF, 1981):

(1) prolonged warm and humid conditions occurring in June through September,
(2) several days over 26 °C with long periods of leaf canopy moisture, and,
(3) can also occur in conjunction with drought stress.

In the 42 days from June 20 to July 31, 1994, at least two of these conditions where present for 14 days. A review of the meteorological data indicates initiating temperatures (mean temperature 18.1 °C; 5 days with a maximum temperature over 24 °C) between June 20 and July 5. This was followed by five days (July 6 - July 10), with moderate temperatures (mean temperature 16.4 °C, no maximum temperature over 24 °C) and significant canopy moisture (measurable precipitation each day and only 1.5 hours of sunshine over the 5 days). This was followed by a two week period (July 11 - July 24) with consistently high temperatures over 26 °C. During these 14 days, the temperature went above 26 °C on 8 days and for a prolonged 5 day period from July 20 - July 24 (average maximum 28.1 °C). For the last 7 days, the high temperatures were coupled with available moisture (18.1 mm total precipitation) and poor drying conditions (4 of 7 days with less than 3 hours of sunshine).

Anthracnose was present at The Oaks well into October. After the initial infection in July of 1994, conditions were favorable for the disease to persist into late fall. In August, 1994, temperatures and precipitation were normal and in September, temperatures were normal with about average precipitation.

Leaf spot diseases

Drechslera leaf spot was first noted at The Oaks in the spring of 1993 on Kentucky bluegrass but by summer it had dissipated. In the fall of 1993, *Septoria* leaf spot disease appeared on certain subplots that were severely affected (i.e. NPK-Ktb and most bag-mowed plots). Similar patterns of appearance and plots affected were observed in 1994. Environmental conditions favoring leaf spot diseases include (Smiley, et.al. 1982):

(1) overcast skies (poor drying conditions),
(2) cool temperatures (12 - 18 ^{o}C), and,
(3) prolonged canopy wetness (greater than 10 hours).

Drechslera leaf spot was first documented at the Oaks on May 21, 1993. In the 35 days prior to this observation (April 16 - May 20), two of the three environmental conditions listed above were present on 20 days. During this time, the mean temperature was 7.5 ^{o}C and the daily maximum was above 12 ^{o}C on 19 days. Also, there were no droughty periods (every week had precipitation) and 18 days had less than 4 hours of sunshine indicating overcast and poor drying conditions.

In July and August, leaf spot likely dissipated as a result of high temperatures and low moisture in August 1993. Appearance of *Septoria* leaf spot in late fall and its distribution was documented on November 18, 1993. In the 34 days prior to this observation (October 15 - November 17), two of the three environmental conditions favoring leaf spot occurred on 15 days. During this period, the mean temperature was 6.2 ^{o}C and the daily maximum was above 12 ^{o}C on 12 days. As in the spring, there was precipitation in every week (i.e. no drought) and 17 days had less than 4 hours of sunshine indicating overcast conditions.

Tables and figures

Below are tables and figures describing the climatic data over 1992, 1993, and 1994. In Table 1.2, monthly averages for six different variables are provided. The figures (1.1 - 1.23) show weekly averages for various variables and also at different times of the year. In the figures, the scale on the X-axis shows the week number (1-52) and the first letter of the month associated with that week. The exact dates associated with each week number can be found in Table 1.1.

Table 1.1 Start and end dates associated with each week.

Week #	Start Date	End Date
1	January 1	January 7
2	January 8	January 14
3	January 15	January 21
4	January 22	January 28
5	January 29	February 4
6	February 5	February 11
7	February 12	February 18
8	February 19	February 25
9	February 26	March 4
10	March 5	March 11
11	March 12	March 18
12	March 19	March 25
13	March 26	April 1
14	April 2	April 8
15	April 9	April 15
16	April 16	April 22
17	April 23	April 29
18	April 30	May 6
19	May 7	May 13
20	May 14	May 20
21	May 21	May 27
22	May 28	June 3
23	June 4	June 10
24	June 11	June 17
25	June 18	June 24
26	June 25	July 1
27	July 2	July 8
28	July 9	July 15
29	July 16	July 22
30	July 23	July 29
31	July 30	August 5
32	August 6	August 12
33	August 13	August 19
34	August 20	August 26
35	August 27	September 2
36	September 3	September 9
37	September 10	September 16
38	September 17	September 23
39	September 24	September 30
40	October 1	October 7
41	October 8	October 14
42	October 15	October 21
43	October 22	October 28
44	October 29	November 4
45	November 5	November 11
46	November 12	November 18
47	November 19	November 25
48	November 26	December 2
49	December 3	December 9
50	December 10	December 16
51	December 17	December 23
52	December 24	December 31

Table 1.2. Monthly meterological summary; Shearwater, Nova Scotia. (Latitude 44.38° N, Longitude 63.30° W, Elevation 51 meters). Source: Environment Canada, Atmospheric Envrionmental Service.

	Daily Maximum Air Temperature (°C)				
Month	*1992*	*1993*	*1994*	*1995*	*60 Year Norm*
January	-1.5	-1.3	-1.9	1.4	-0.4
February	-0.6	-2.9	-1.7	-0.2	-0.3
March	1.0	3.0	3.4	2.5	3.3
April	6.0	8.1	10.4	8.0	8.2
May	13.8	14.1	13.3	12.4	13.9
June	19.6	18.0	20.1	20.2	19.2
July	20.3	21.3	23.9	22.8	22.6
August	22.3	22.5	22.2	22.9	22.8
September	19.0	19.3	18.3	19.3*	18.8
October	12.7	12.5	13.8	.	13.1
November	6.1	8.3	9.7	.	7.8
December	2.0	3.4	3.1	.	2.3

	Daily Minimum Air Temperature (°C)				
Month	*1992*	*1993*	*1994*	*1995*	*60 Year Norm*
January	-9.8	-10.7	-13.3	-5.2	-8.5
February	-9.4	-13.2	-10.9	-10.2	-8.3
March	-7.0	-6.8	-4.3	-4.6	-4.5
April	-1.6	0.2	1.3	-0.6	0.4
May	3.6	5.3	4.4	4.1	5.2
June	9.9	8.5	10.4	9.9	10.2
July	12.1	12.7	15.8	14.3	14.0
August	13.9	14.2	13.9	13.7	14.5
September	10.7	11.2	10.0	10.3*	10.8
October	4.7	2.8	5.5	.	5.8
November	-0.7	-0.4	1.0	.	1.0
December	-5.4	-4.1	-5.0	.	-5.5

	Daily Mean Air Temperature (°C)				
Month	*1992*	*1993*	*1994*	*1995*	*60 Year Norm*
January	-5.7	-6.0	-7.6	-1.9	-4.6
February	-5.0	-8.1	-6.3	-5.1	-4.8
March	-3.0	-1.9	-0.5	-1.1	-1.0
April	2.2	4.2	5.9	3.8	3.9
May	8.7	9.7	8.9	8.3	8.9
June	14.8	13.3	15.3	15.1	13.9
July	16.2	17.0	19.9	18.5	17.5
August	18.1	18.4	18.1	18.3	17.9
September	14.9	15.3	14.2	.	14.4
October	8.7	7.7	9.7	.	9.3
November	2.7	4.0	5.4	.	4.2
December	-1.7	-0.4	-0.9	.	-1.7

	Degree Days (Base = 5 °C)				
Month	*1992*	*1993*	*1994*	*1995*	*60 Year Norm*
January	0.0	0.0	0.0	9.7	0.8
February	0.0	0.0	6.8	0.0	0.3
March	0.0	10.0	0.6	0.0	1.9
April	12.4	28.0	47.1	26.1	21.8
May	124.9	151.7	120.0	109.4	123.9
June	292.5	247.2	308.7	301.2	265.8
July	348.0	372.9	461.4	418.9	387.0
August	407.6	415.0	405.8	413.2	399.6
September	295.8	308.5	274.8	.	281.7
October	119.7	86.9	145.7	.	139.6
November	20.9	27.1	59.9	.	40.6
December	2.2	15.7	3.2	.	6.1
Total	1624	1663	1834	.	1669

	Total Precipitation (mm)				
Month	*1992*	*1993*	*1994*	*1995*	*60 Year Norm*
January	108.2	60.0	132.0	129.6	145.5
February	170.8	128.2	41.8	133.0	113.7
March	93.6	154.7	243.2	50.7	124.8
April	45.4	102.2	150.4	107.2	123.6
May	47.8	83.8	164.2	117.6	118.0
June	57.4	100.4	113.6	184.0	112.9
July	93.2	107.0	24.8	228.7	104.6
August	65.0	72.6	100.0	60.0	108.9
September	89.0	106.8	104.6	46.2*	99.5
October	83.8	192.8	57.5	.	135.8
November	105.2	105.8	211.2	.	156.7
December	117.3	213.4	228.9	.	169.2

	Bright Sunshine (Hours)				
Month	*1992*	*1993*	*1994*	*1995*	*60 Year Norm*
January	105.6	92.4	124.8	79.3	113.0
February	98.8	132.5	146.4	156.6	129.7
March	154.5	159.7	107.5	107.2	146.1
April	145.5	147.0	215.6	192.7	157.5
May	210.7	170.7	179.2	201.6	199.3
June	239.6	213.9	249.4	266.3	215.2
July	216.2	245.6	210.1	220.3	224.2
August	233.0	226.9	207.4	286.8	224.6
September	178.0	155.8	189.9	.	181.5
October	167.2	160.2	188.9	.	154.2
November	75.2	115.7	137.7	.	107.6
December	79.4	82.4	118.6	.	96.2

* Monthly averages when provided for September 1995 are based only on the first 18 days of the month.

Figure 1.1 Maximum Daily Temperature - 1992

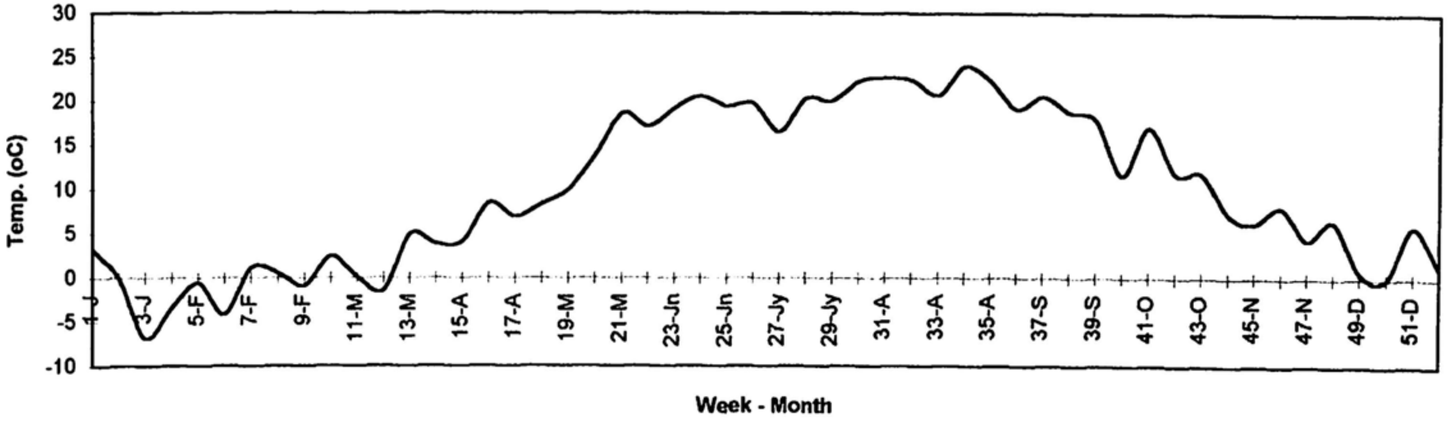


Figure 1.2 Maximum Daily Temperature - 1993

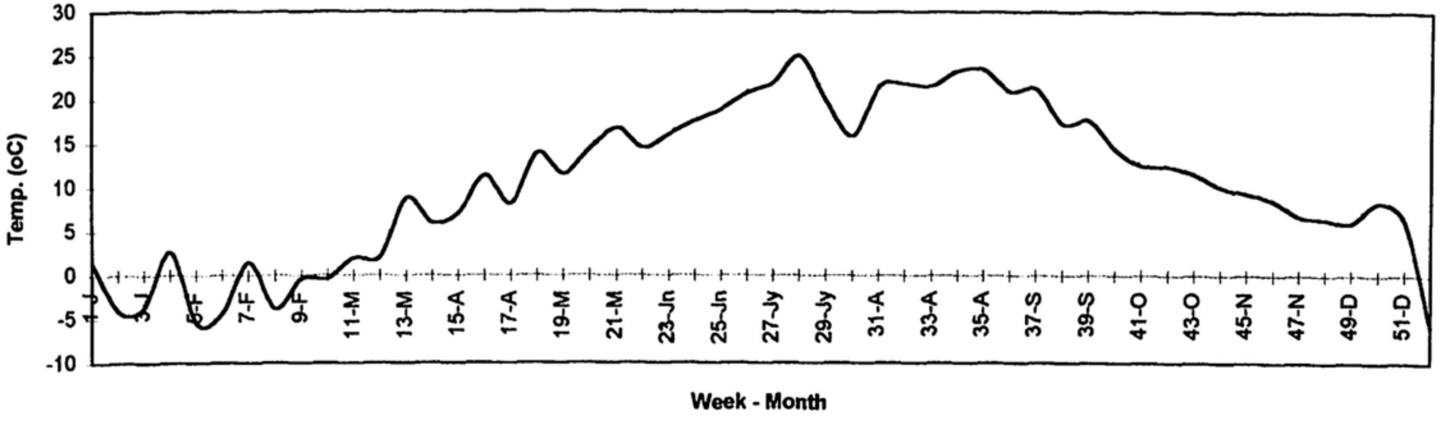


Figure 1.3 Maximum Daily Temperature - 1994

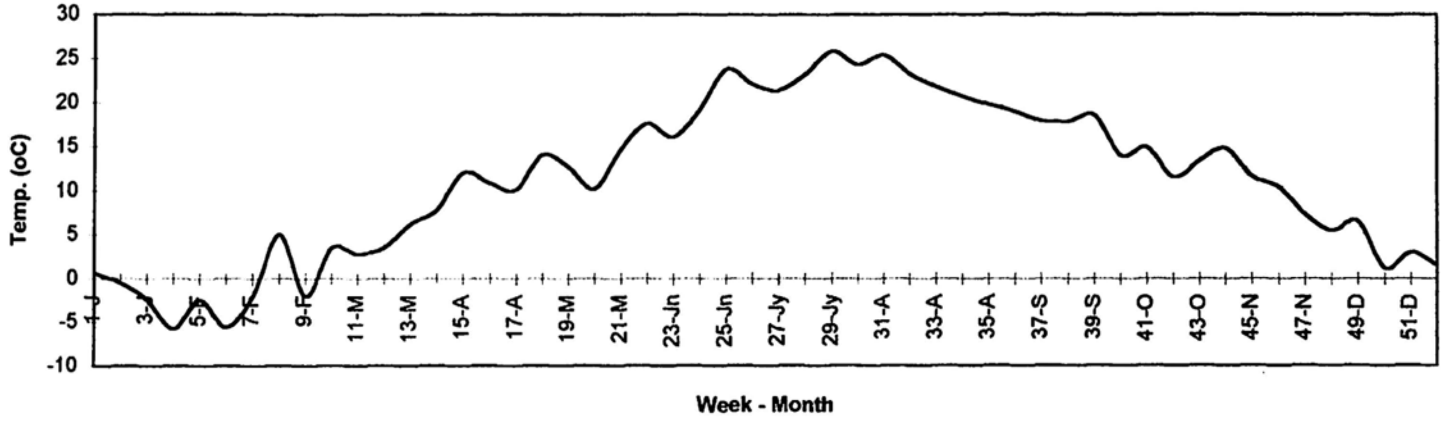


Figure 1.4 Maximum Daily Temperature - 1992, 1993, 1994

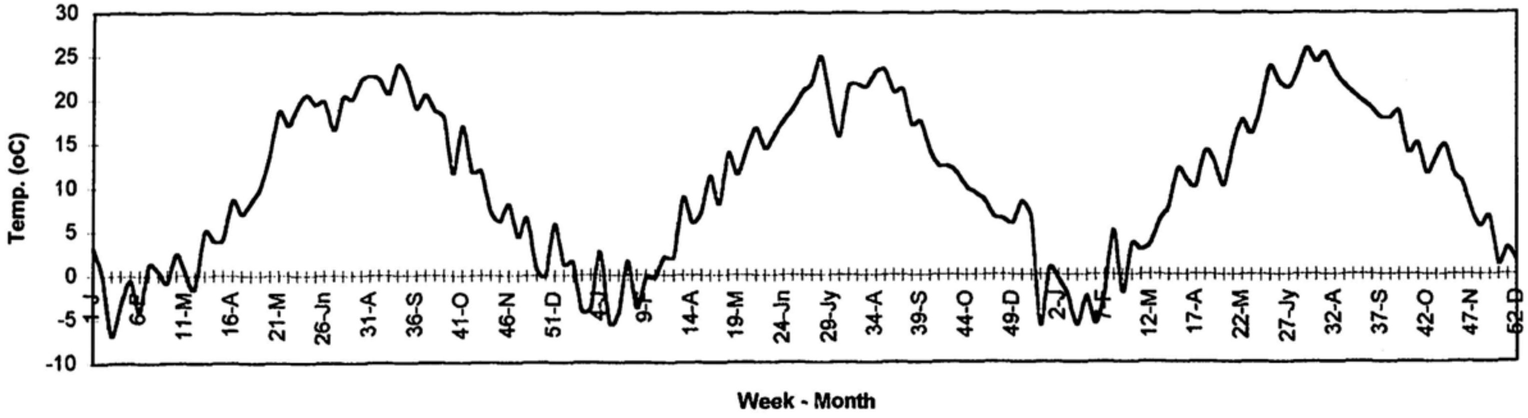


Figure 1.5 Minimum Daily Temperature - 1992

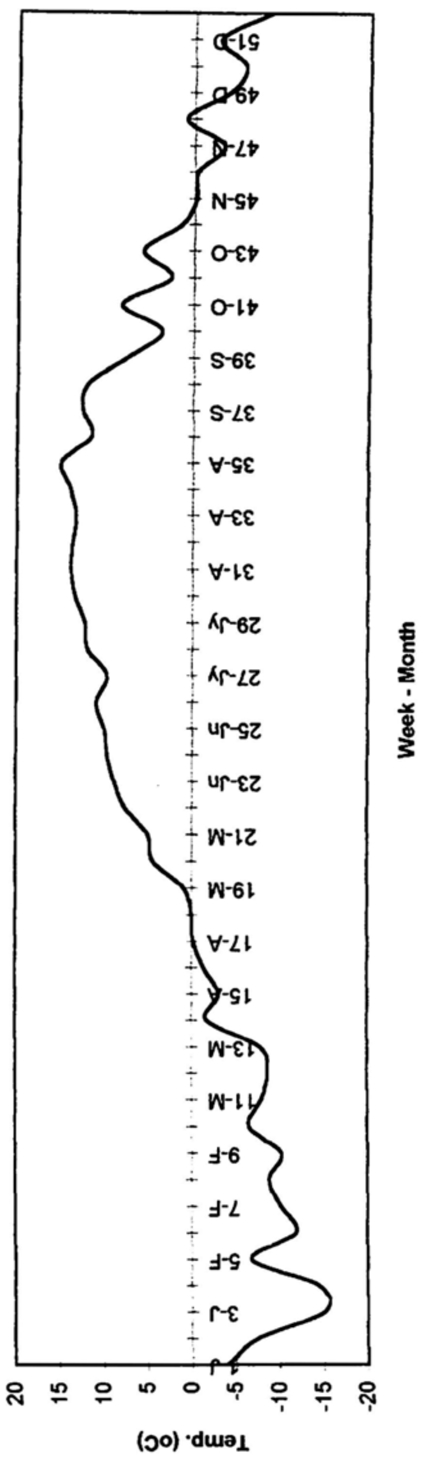


Figure 1.6 Minimum Daily Temperature - 1993

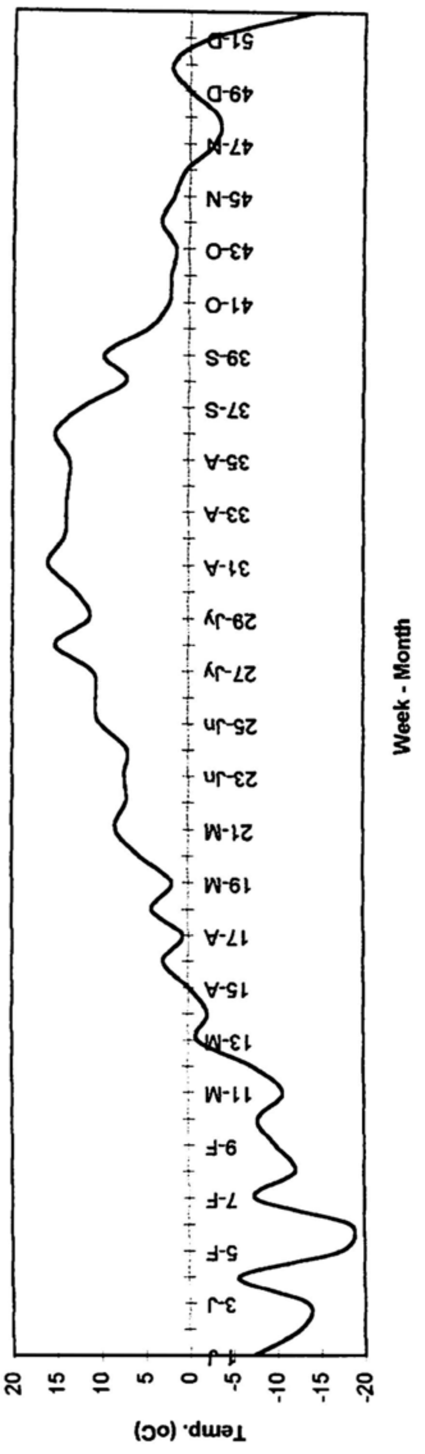


Figure 1.7 Minimum Daily Temperature - 1994

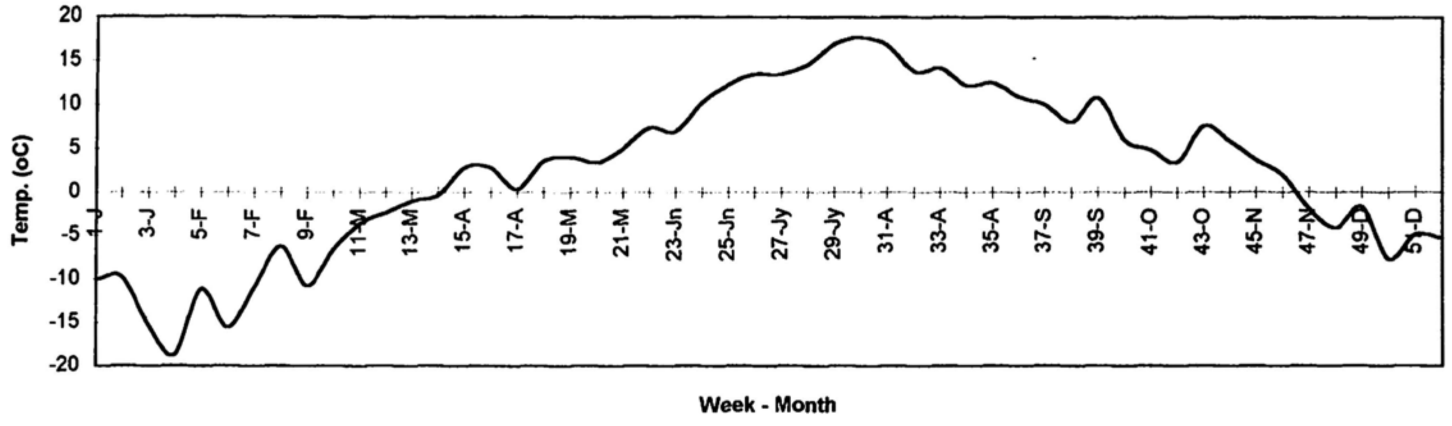


Figure 1.8 Minimum Daily Temperature - 1992,1993,1994

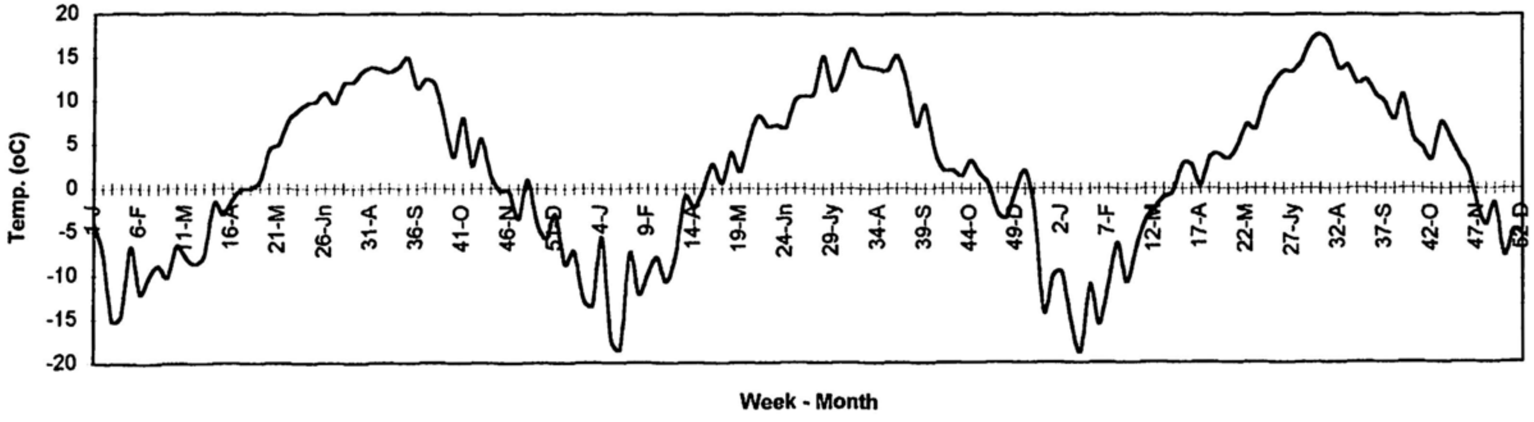


Figure 1.9 Mean Daily Temperature - Spring and Fall, 1992

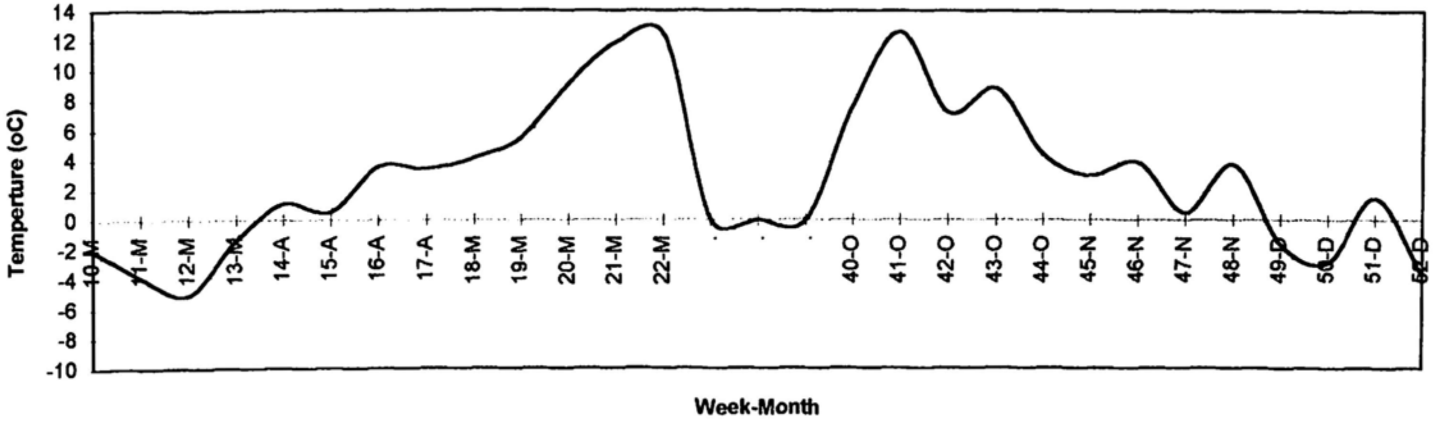


Figure 1.10 Mean Daily Temperature - Spring and Fall, 1993

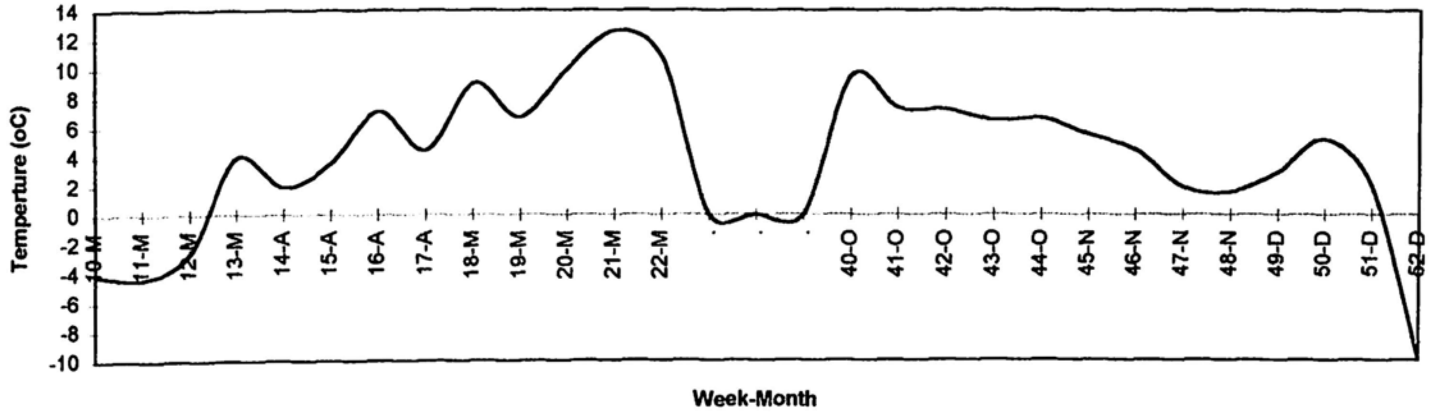


Figure 1.11 Mean Daily Temperature - Spring and Fall, 1994

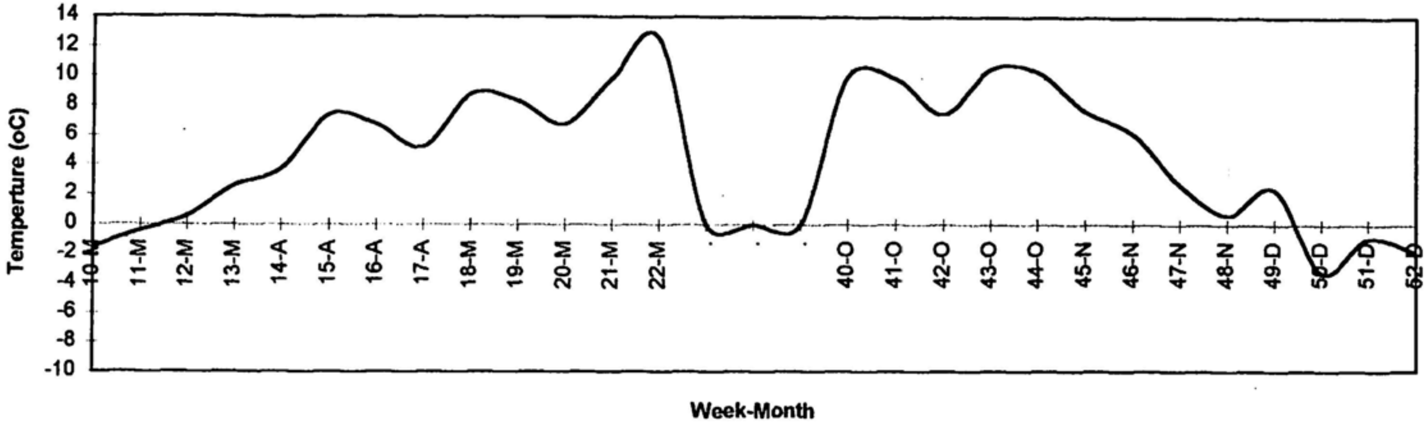


Figure 1.12 Total Weekly Precipitation - 1992

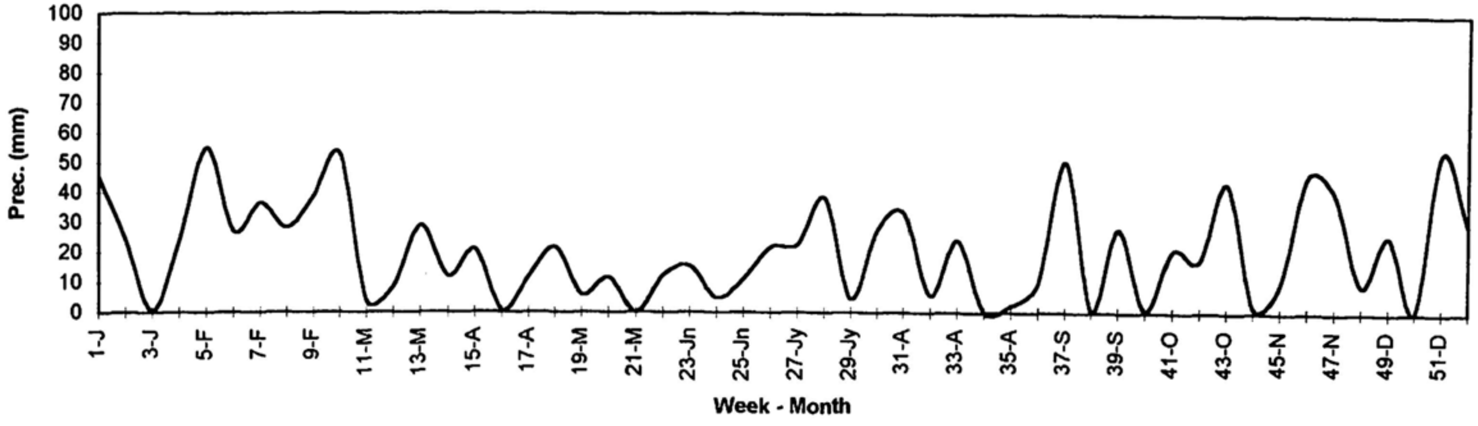


Figure 1.13 Total Weekly Precipitation - 1993

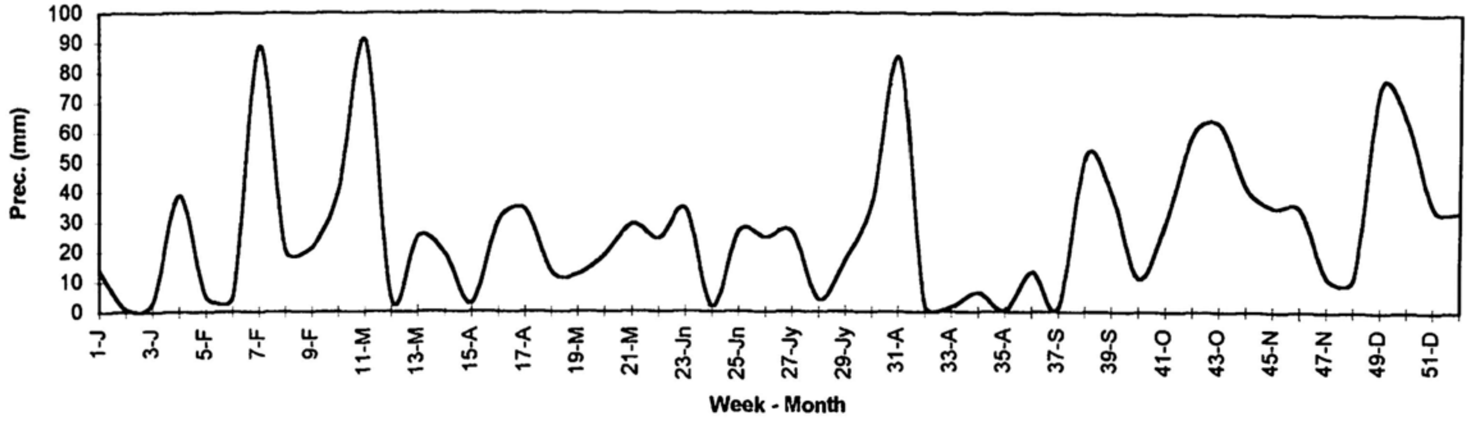


Figure 1.14 Total Weekly Precipitation - 1994

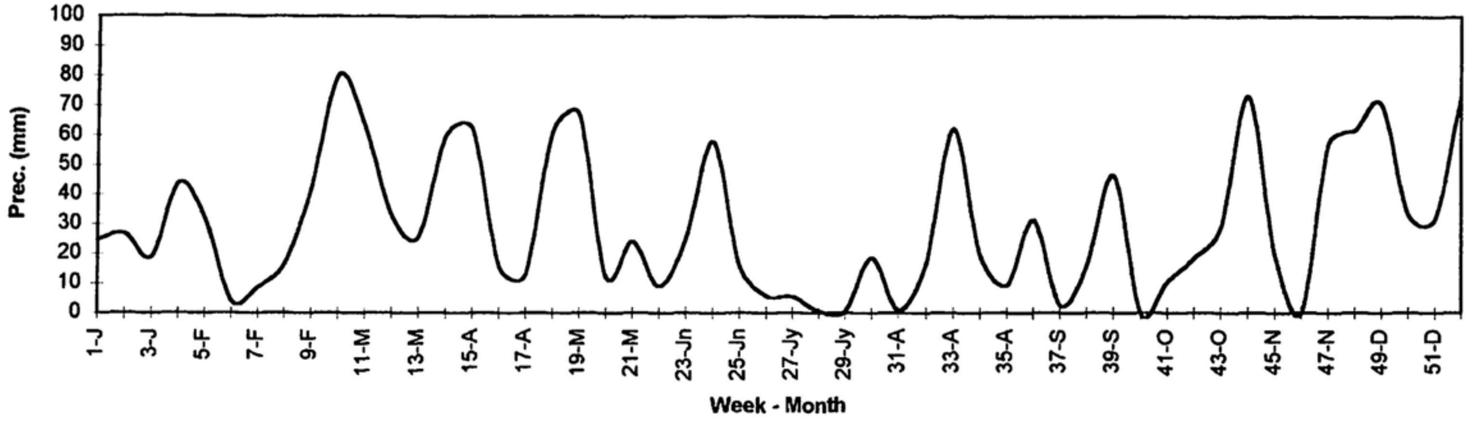
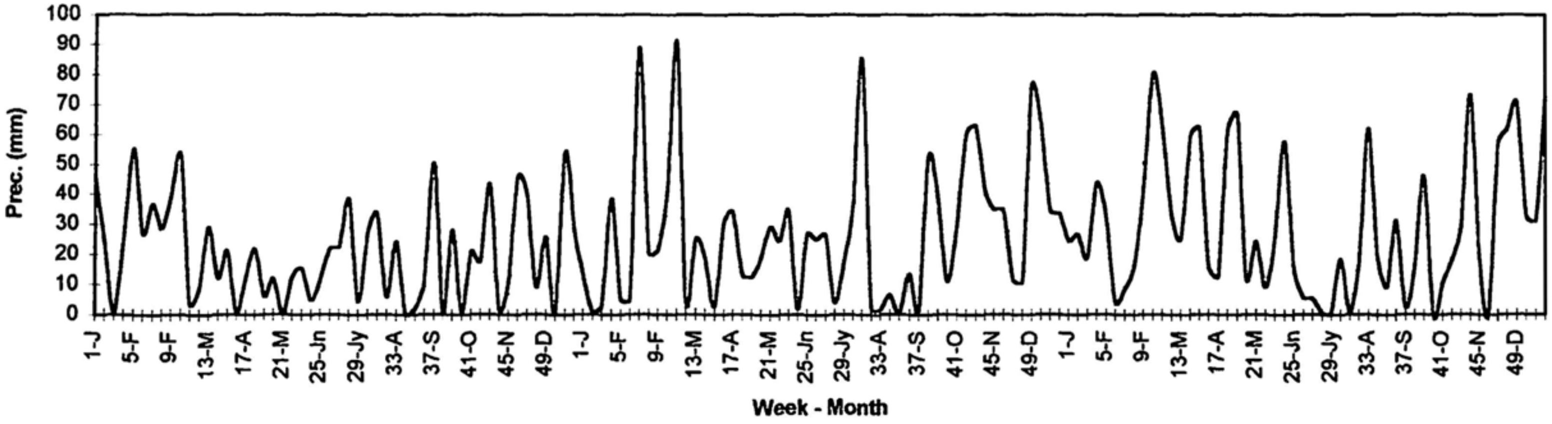


Figure 1.15 Total Weekly Precipitation - 1992,1993,1994



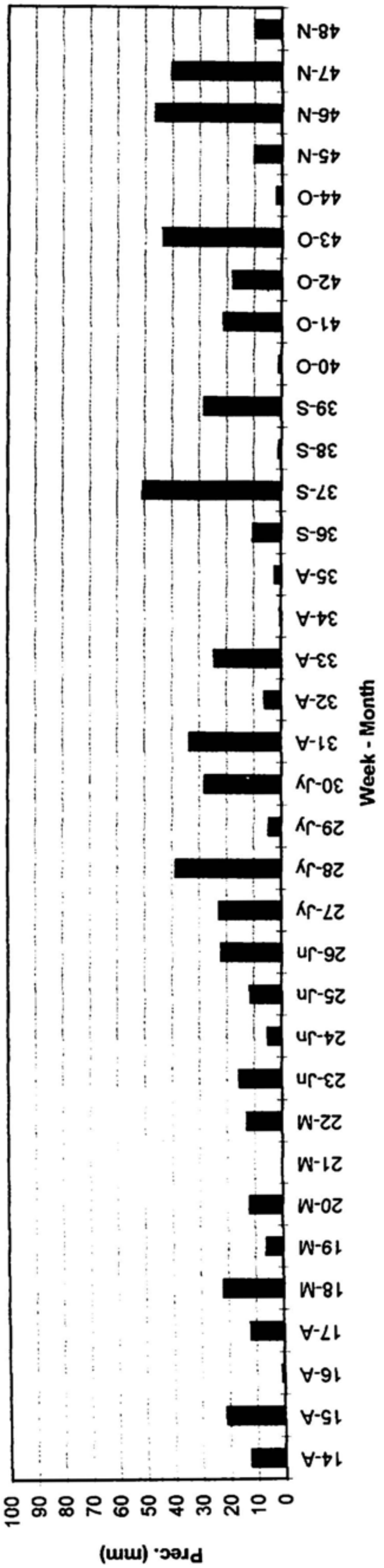


Figure 1.16 Total Weekly Precipitation: April - November 1992

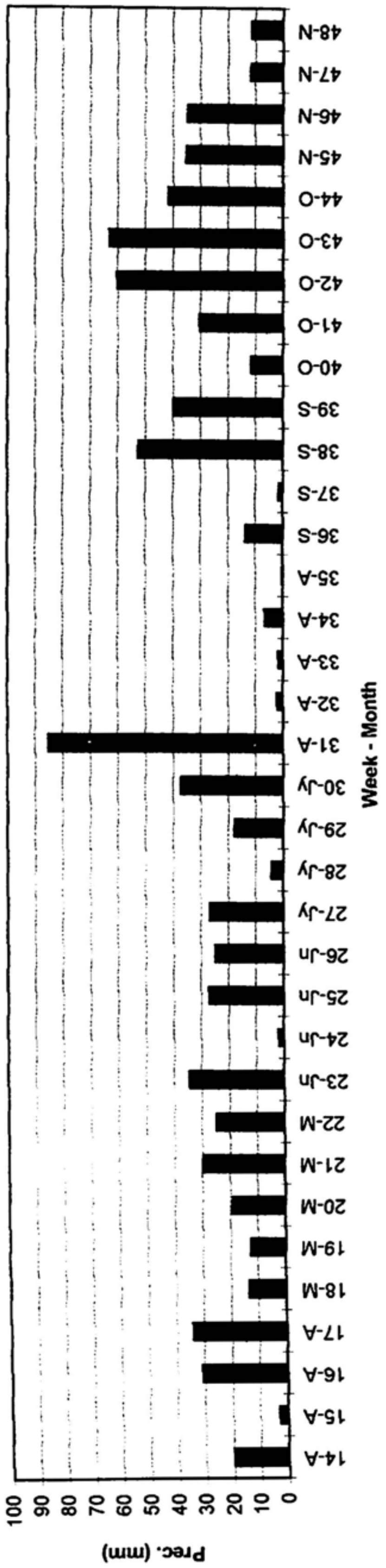


Figure 1.17 Total Weekly Precipitation: April - November 1993

Figure 1.18 Total Weekly Precipitation: April - November 1994

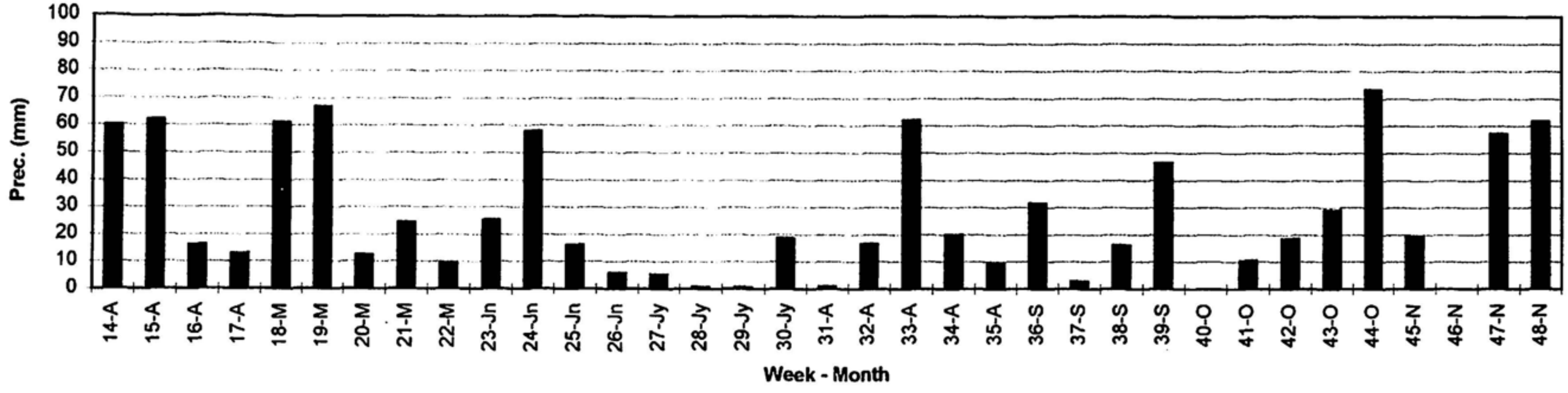


Figure 1.19 Total Weekly Precipitation: April - Mid-September 1995

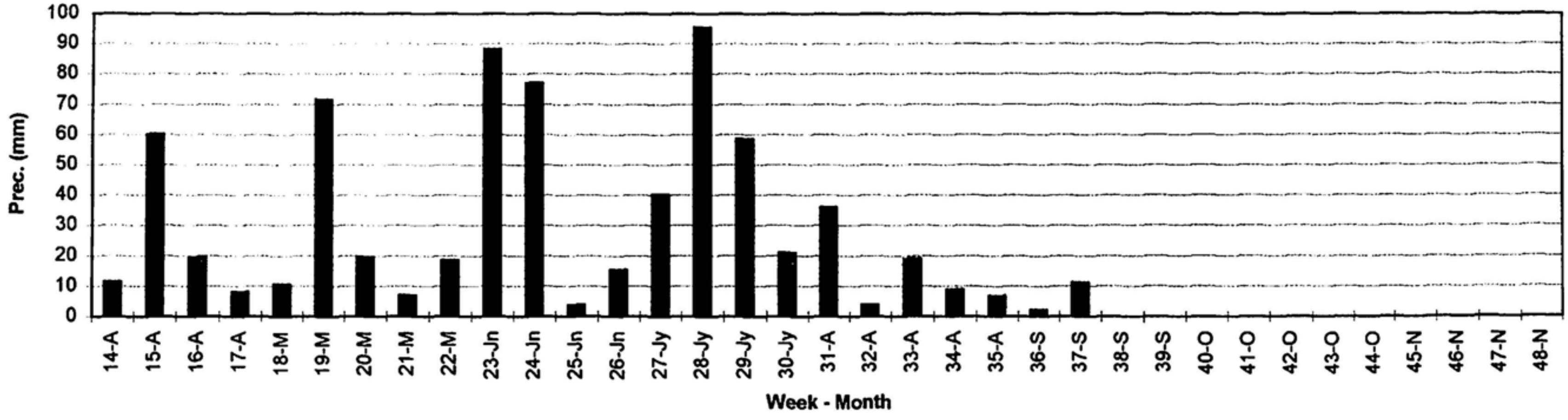


Figure 1.20 Average Snow Depth - 1992

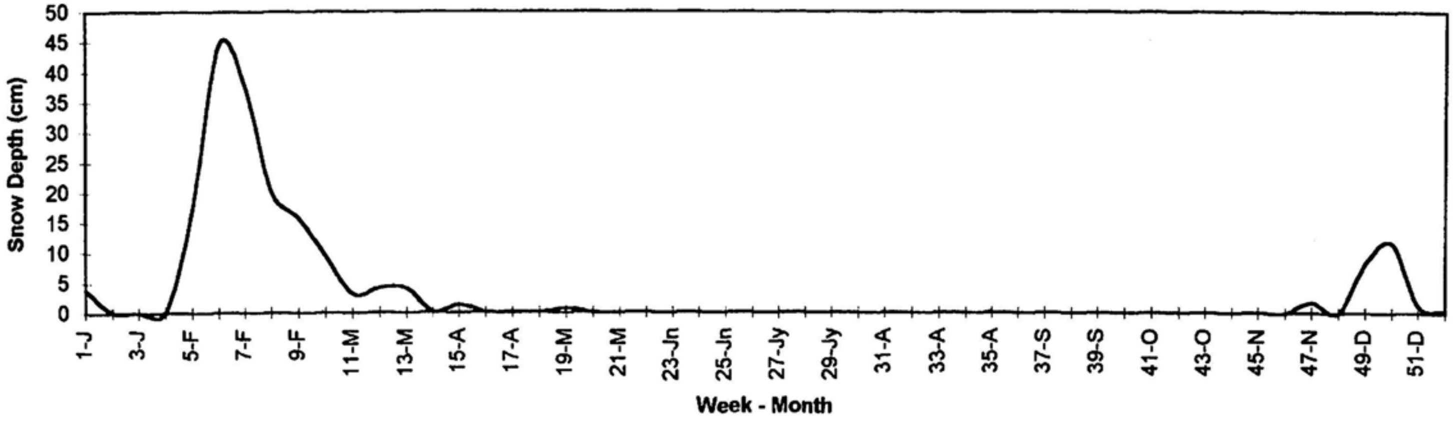


Figure 1.21 Average Snow Depth - 1993

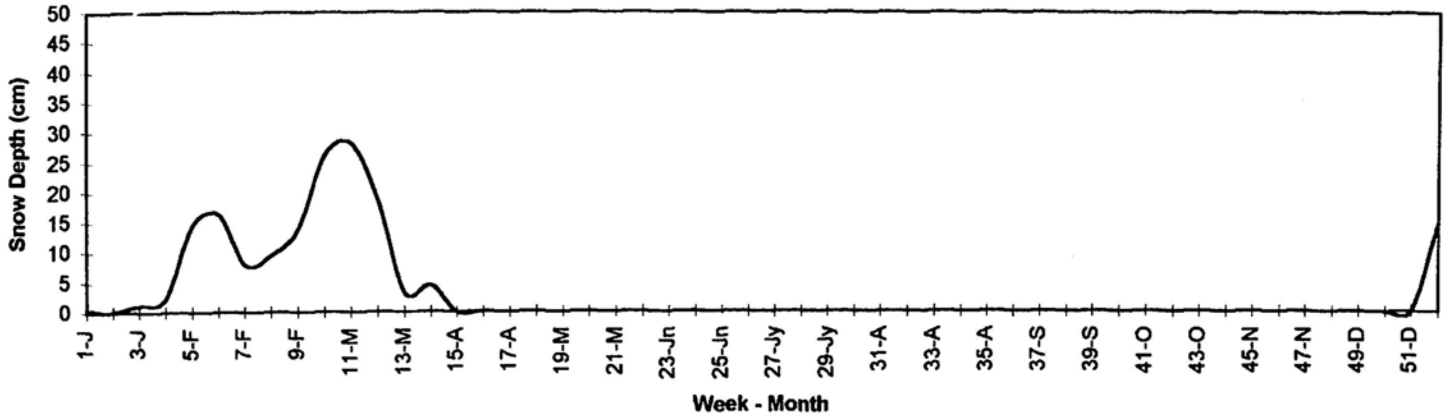


Figure 1.22 Average Snow Depth - 1994

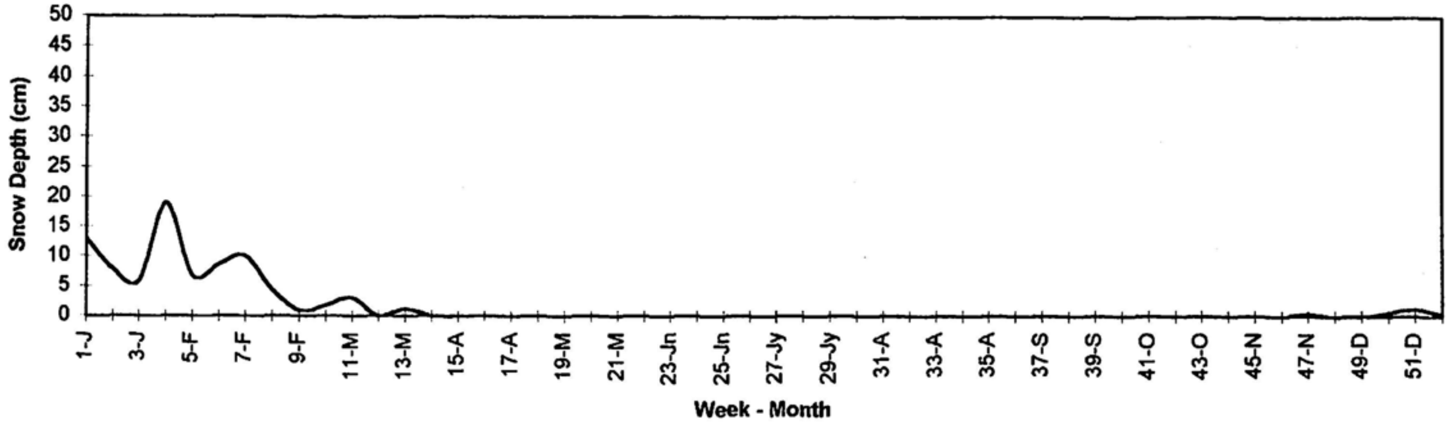
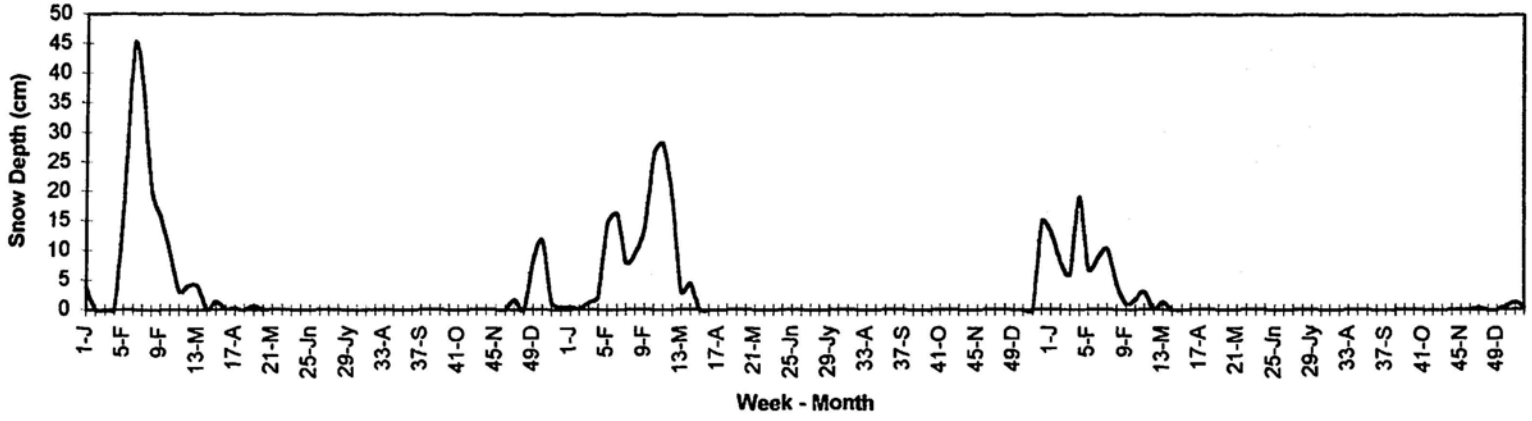


Figure 1.23 Average Snow Depth - 1992,1993,1994



Appendix 2A. Questionnaire feedback: The Oaks field day, September 17, 1994.

On September 17, 1994, a public Field Day was held at The Oaks. Several tours were held through the day where participants visited a series of "Stations" set up on The Oaks turfs. At a number of the stations, participants were asked to rank various plots. The results are presented below (Exercise I, II).

Following their tour, visitors were asked to provide feedback on what they considered important in regards to "turf aesthetics", on different turf mixtures, and on their feeling about having clover in turfs by filling out a questionnaire. The questions of the questionnaire are provided below and the responses are summarized (Exercise III). Twenty of the participants filled out questionnaires.

EXERCISE I. Identification of least and most fertilized subplots within a Control main plot.

1A. F Field Control main plot. Identify the plot that looks the least fertilized.

Tour	Undecided	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3	OF3X
1				4	11				
2			3		9	2			
3				1	7	2			
Total			3	5	27	4			

Comments: 69% identified the bag mowed plot as the least fertilized.
7.7% identified the zero fertilized plot as the least fertilized.

1B. F Field Control main plot. Identify the plot that looks the most fertilized.

Tour	Undecided	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3	OF3X
1								18	1
2								16	
3								9	
Total								43	1

Comments: 98% identified the summer fertilized plot as the most fertilized.

2A. B Field Control main plot. Identify the plot that looks the least fertilized.

Tour	Undecided	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3	OF3X
1				1	6		5		1
2					9	1	1		4
3	4			1	4				
Total	4			2	19	1	6		5

Comments: 51% identified the bag mowed plot as the least fertilized.
No one identified zero fertilized plots as the least fertilized.

2B. B Field Control main plot. Identify the plot that looks the most fertilized.

Tour	Undecided	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3	OF3X
1						2		9	
2							3	10	1
3	2						1	6	
Total	2					2	4	25	1

Comments: 74% identified the summer fertilized plot as the most fertilized.

EXERCISE II. In this exercise, participants were asked to examine the NPK-Ktb and NPK-Ecomix subplots and describe any differences they observed.

Response. NPK-Ktb plot was described as:

- greener
- having more clover
- having bigger clover
- more succulent
- having bigger grass
- more patchy (due to *Agrostis*)
- thicker

EXERCISE III. Questionnaire.

Quality criteria

Following are some of the characteristics considered when quality of turfs is being assessed. How important are they to you? Please rate them for the front lawn, and then indicate whether the feature is of less significance to you for a back lawn:

Question 1. Early greening up of grass in spring: Is it important to you to see green grass from late April or early May on (versus late May)? Please rate importance on scale of 1 to 5 (1 not important to 5 very important; indicate 0 if no opinion: Rating # ________

Concern for back lawn: a. Same as for front b. Less concerned
c. More concerned; (circle a, b, or c).

Response. Of the participants who responded to this question:

Scale 1: 25%
Scale 2: 20%
Scale 3: 35%
Scale 4: 20%
Scale 5: 0%

In addition, 61% of participants showed the same concern for the back lawn, 22% were less concerned, and 17% were more concerned.

Question 2. Thickness/density. How important to you is it to have a very dense carpet of grass? Please rate importance on scale of 1 to 5 (1 not important to 5 very important; indicate 0 if no opinion: Rating #_____

Concern for back lawn: a. Same as for front b. Less concerned
c. More concerned

Response. Of the participants who responded to this question:

Scale 1: 0%
Scale 2: 5%
Scale 3: 50%
Scale 4: 45%
Scale 5: 0%

In addition, 41% of participants showed the same concern for the back lawn, 35% were less concerned, and 29% were more concerned.

Question 3. Dandelion and plantain. Please indicate what's desirable and what's acceptable. Circle one letter for acceptable and one for desirable.

Acceptable:
a. None b. Less than 5% cover c. Less than 10% d. Any level OK
e. No opinion

Desirable:
a. None b. Less than 5% cover c. Less than 10% d. Any level OK
e. No opinion

Concern for back lawn: a. Same as for front b. Less concerned
c. More concerned

Response. Of the participants who responded to this question:

	Acceptable	Desirable
None	20%	75%
Less than 5%	70%	10%
Less than 10%	5%	15%
Any level OK	5%	0%
No opinion	0%	0%

In addition, 67% of visitors showed the same concern for a back lawn, 17% were less concerned, 17% were more concerned.

Question 4. Greenness of grass through the season. You prefer (circle one):

a. Light green b. In between c. Very dark green d. A blend of greens
e. No opinion

Concern for back lawn: a. Same as for front b. Less concerned
c. More concerned

Response. Of the participants who responded to this question:

Light green	0%
In between	40%
Very dark green	10%
A blend of greens	45%
No opinion	5%

In addition, 75% of participants showed the same concern for a back lawn, 15% were less concerned, and 10% were more concerned.

Question 5. Fine (thin) grass blades versus thick or wide blades:

I prefer: a. all thin blades, b. all thick, c. a blend of the two d. no opinion

Concern for back lawn: a. Same as for front b. Less concerned
c. More concerned

Response. Of the participants who responded to this question:

All thin blades	0%
All thick blades	5%
A blend of the two	90%
No opinion	5%

In addition, 72% of participants showed the same concern for a back lawn, 11% were less concerned, and 17% were more concerned.

Question 6. Summer browning: Is it worth watering to avoid it?

a. I would tolerate it b. I would water c. no opinion

Concern for back lawn: a. Same as for front b. Less concerned
c. More concerned

Response. Of the participants who responded to this question:

I would tolerate it	47%
I would water	53%
No opinion	0%

In addition, 61% of participants showed the same concern for a back lawn, 28% were less concerned, and 11% were more concerned.

Question 7. Height of mowing:

I prefer a. very short mow (lowest setting) b. medium
c. highest setting (usually 3")

Concern for back lawn: a. Same as for front b. Less concerned
c. More concerned

Response. Of the participants who responded to this question:

Very short mow	0%
Medium	74%
Highest setting	26%

In addition, 75% of the participants showed the same concern for a back lawn while 25% were less concerned.

Question 8. Brown patches: (e.g. due to chinch bug, dog urine, fertilizer burn, drought).

I can: a. tolerate some b. tolerate none c. No opinion

Concern for back lawn: a. Same as for front b. Less concerned
c. More concerned

Response. Of the participants who responded to this question:

Tolerate some	42%
Tolerate none	53%
No opinion	5%

In addition, 78% of the participants showed the same concern for a back lawn, 11% were less concerned and 11% were also more concerned.

Question 9. Other features that are important to you:

Response. This was an "open" question. Only one person responded and the concern raised was the ability to cope with high traffic areas.

<u>Comparison of mixtures</u>

There are four mixtures sown at Site 4.

1. Tall Fescues 2. Ecomix 3. Greenfast
4. Greenfast +35% Tall Fescues

The grass species composition of the mixes is shown on page 27 of the booklet. Clover grew into 1, 2, & 3 in 1993 from a seedbank that was established under the old (pre-1992) turf . Number 4 was planted in the fall of '93, and clover has not yet developed in it.

Question 10. Which mixture is overall most appealing to you <u>for a high profile lawn</u> (e.g. front lawn): Circle one of the numbers:

1. Tall Fescues 2. Ecomix 3. Greenfast 4. Greenfast +35% Tall Fescues

5. No difference 6. None is appealing (I would not accept any on a front lawn).

Response. Of the participants who responded to this question:

Tall Fescues	0%
Ecomix	21%
Greenfast	0%
Greenfast+35% TF	79%
No Difference	0%
None is appealing	0%

Question 11. If you answered one of (1) (2) (3) (4), can you comment what you particularly like about the mixture? Or if you answered 6, can you state why?

Response. A selection of the responses follows:

- low profile and homogeneous
- soft look and varied colour
- didn't like the wide thick blades of (1) and felt the colour of (4) was patchy
- liked the colour and no clover
- colour quality and texture
- healthy looking and combination of textures makes patchiness hard to discern

Question 12. Do you consider that the presence of clover in the mixtures 1, 2, & 3:

a. Detracts from its aesthetic appeal? b. Probably enhances it
c. No opinion d. Other

Response. Of the participants who responded to this question:

Detracts from aesthetics	22%
Probably enhances	61%
No opinion	11%
Other	6%

Clover in lawns

Complaints often heard about clover include the following; please indicate if you share the concerns:

-it stains (green) more readily than grass:
Q. 13: Have you experienced this problem? a. Yes b. No

-the white flowers (appearing in late June through most of July) are unattractive
Q 14 Do you agree? a. Yes b. No

-the white flowers attract bees which sting children
Q. 15 Do you know of children who have been stung by bees feeding on clover in lawns? a. Yes b. No

Q 16. Is the bee problem of sufficient concern generally that you think clover on public turfs should be controlled by herbicides? a. Yes b. No c. Other comments:

-it's usually associated with weeds
Q. 17 Do you agree? a. Agree b. disagree c. no opinion

- it forms unsightly patches
Q. 18 Do you agree? a. Agree b. disagree c. no opinion

Response. Of the participants who responded to this question:

	Yes	No	Agree	Disagree	No Opinion
Question 13	0%	100%			
Question 14	47%	53%			
Question 15	5%	95%			
Question 16	0%	100%			
Question 17			10%	68%	22%
Question 18			15%	55%	30%

Clover has a number of important ecological benefits: Some of the most important are:

- It is a legume and capable of using atmospheric N_2 gas in place of soil nitrates or applied N fertilizer. This reduces the need for N fertilizer; clover based lawns need only 0.25 to 1 lb of N for maximum aesthetic appearance (best applied in as dormant feed in late fall). Using less fertilizer N results in less potential pollution of groundwater, and reduces needs for other nutrients and lime (high levels of N result in leaching of other nutrients and will acidify soil).

- Clover is more drought resistant than most local grasses, so clover based lawns will hold their greenness much better through late July and August.

- Clover adds diversity to the system overall which makes it a more stable ecological system (more resistant to pests, climatic variation etc.), as a broadleaf, it competes well with broadleaf weeds.

Question 19. Clover is killed by broadleaf herbicides, hence is usually eliminated in herbicide controlled lawns. Taking into account the benefits of clover, if there were a herbicide available that killed broad leaf weeds, but not clover, would you want it used?

a. Yes b. No c. I would not use a herbicide in any case d. No opinion

Response. Of the participants who responded to this question:

Yes	15%
No	35%
No herbicide ever	40%
No opinion	10%

Clover is not an inevitable component of organically managed turfs, unless you have an exceptionally high seedbank as on the B field at The Oaks. Where there is not a high seedbank, clover can be kept at very low levels by weeding, and favoring the grass (e.g. by high mowing, relieving N deficiency in grasses).

Question 20. In an organically managed turf, would you prefer not to have clover?

On front lawn
a. I prefer not to have clover b. Either way c. I want clover
d. No opinion

Back lawn
a. I prefer not to have clover b. Either way c. I want clover
d. No opinion

Response. Of the participants who responded to this question:

	Front Lawn	Back Lawn
No clover	10%	5%
Either way	50%	45%
I want clover	35%	45%
No opinion	5%	5%

Another option is to overseed clover into a lawn (or include it in the original seed mix) in order to create a diffuse distribution of clover and avoid the patchy appearance that can develop when clover newly invades a lawn (as on the F field at The Oaks). This also allows you to benefit from the advantages of clover. A disadvantage is that you would not be able to use herbicides to control weeds.

Question 21. Assuming that weeds could be controlled adequately with a few hand weedings (done by yourself or hired help), would this option (TOLERATE CLOVER, REMOVE WEEDS) be acceptable?

For front lawn, tolerate clover remove weeds is:
a. desirable b. acceptable c. not acceptable d. no opinion

For back lawn:
a. desirable b. acceptable c. not acceptable d. no opinion

Response. Of the participants who responded to this question:

	Front Lawn	Back Lawn
Desirable	45%	45%
Acceptable	50%	50%
Not acceptable	5%	5%
No opinion	0%	0%

Other information that will help us analyze the responses to this questionnaire:

		Response
• Do you recycle newspapers, cans etc.	a. yes	100%
	b. no	0%

		Response
• Do you currently make compost on your property?	a. yes	65%
	b. no	35%

		Response
• Is it important to you to have a high quality front lawn?	a. yes	65%
	b. no	35%

		Response
• Do you hand weed or use herbicide or both or neither?	a. Hand weed	55%
	b. Herbicide	0%
	c. Both	15%
	d. Neither	30%

		Response
• Do you apply fertilizer to your lawn?	a. None	40%
	b. Some	55%
	c. Regularly	5%

		Response
• Do you use organic fertilizers?	a. None	55%
	b. Some	40%
	c. Regularly	5%

Participants were also asked to provide any questions they had in regards to turf maintenance. A sample of the questions included:

(1) How do you get rid of chinch bug?
(2) How do you seed new turf?
(3) How do you seed clover?
(4) Will fertilizers wash off slopes?
(5) How often should one mow and at what height?
(6) How do you control weeds when the neighbor has a high population?
(7) Doesn't dead grass accumulate when you mulch mow?

(8) What is thatch?
(9) Why would you use mixtures?
(10) How do you get rid of coltsfoot?
(11) What effects do trees have on fertilizer requirements?
(12) Do you really need a mulch mower?
(13) What about using hand mowers?
(14) If the soil is clay and hard do you have to completely renovate to establish turf?
(15) What did we use at First Lake? Where do we buy fertilizers?
(16) Where do we obtain groundcovers?
(17) What groundcovers spread the fastest?
(18) What about planting groundcovers in woodland/greenbelt?
(19) What is the cost of composters?
(20) What about weed seeds in the compost?
(21) What about rats?

Appendix 2B. Questionnaire feedback: The Oaks technical workshop, October 5, 1994.

On October 5, 1994, a technical workshop was held at The Oaks for people working within the turfgrass industry. A tour was held where participants visited a series of "Stations" set up on The Oaks turfs. At a number of the stations, participants were asked to rank various plots and the results are presented below (Exercise I, II,III).

Following their tour of The Oaks, visitors were asked to conduct independent evaluations on mixtures and the overall quality of the organic managed turf. The questions are given below with the results obtained (Exercise IV).

EXERCISE I. Identification of least and most fertilized subplots within a Control main plot.

1A. F Field Control Main Plot. Identify the plot that looks the least fertilized.

Tour	Undecided	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3	OF3X
Total				4	45				

Comments: 92% identified the bag mowed plot as the least fertilized.

1B. F Field Control Main Plot. Identify the plot that looks the most fertilized.

Tour	Undecided	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3	OF3X
Total								48	

Comments: 100% identified the summer fertilized plot as the most fertilized.

2A. B Field Control Main Plot. Identify the plot that looks the least fertilized.

Tour	Undecided	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3	OF3X
Total	4			9	10				3

Comments: 38% identified the bag mowed plot as the least fertilized.
No one identified zero fertilized plots as the least fertilized.

2B. B Field Control Main Plot. Identify the plot that looks the most fertilized.

Tour	Undecided	OF0	OF0	OF1m	OF1b	OF2	OF2f	OF3	OF3X
Total	12	5				2	7	9	

Comments: 26% identified the summer fertilized plot as the most fertilized. 34% of industry professionals were unable to identify any discernible difference between plots.

EXERCISE II. In this exercise, participants were asked to examine the NPK-Ktb and NPK-Ecomix subplots and describe any differences they observed.

Response. NPK-Ktb plot:

- was lighter green
- had finer grass
- was patchy

NPK-Ecomix plot:

- had less clover
- had finer blades
- was more uniform

EXERCISE III. In this exercise, participants were asked to review the main plots and identify which plot had the darkest green colour and which had lightest.

Darkest green

Field	Control	Compost	B.Waste	NPK
F Field			7	
B Field		14		

Lightest green

Field	Control	Compost	B.Waste	NPK
F Field	2		1	3
B Field				1

EXERCISE IV. Questionnaire.

Mixture/organic turf quality evaluations

Question 1. Give a rating out of 10 for each of the following characteristics for each of the four mixture plots at Station 7.

For color, density, and overall aesthetic value,

-a value of 10 should correspond to the best possible quality,
-a value of 5 or 6 to "average for the trade",
-values of 1-5 to less than acceptable turf.

The height rating should be for desirability (the turf was mowed on Monday);
10 = the best possible, 1 = totally undesirable.

In the final two columns, please indicate whether the turf in the plot would be:
Unacceptable (U), Acceptable (A), or Desirable (D) for commercial and residential properties.

Response. The response to this question has been broken down into two tables, one for landscape professionals (total of 5 responses; Edmonds' personnel responses not included), and one for landscape students (total of 10 responses).

Response of landscape professionals.

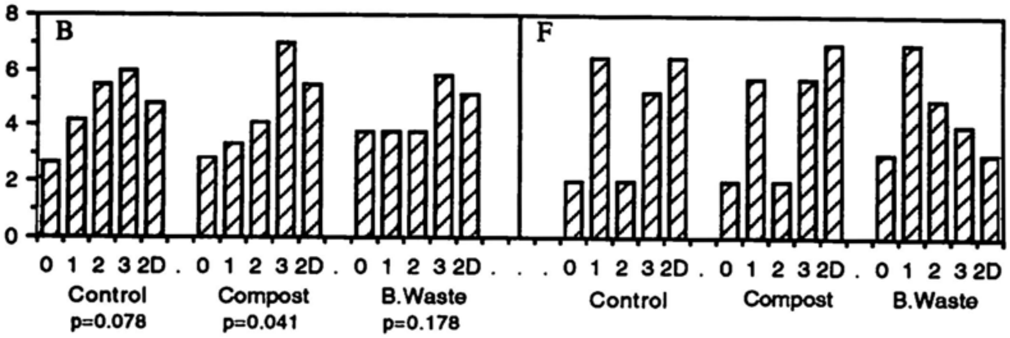
	Average Value Out of 10 With Range ( )				% Responded					
Plot	**Color**	**Density**	**Overall**	**Height**	**Commercial**			**Residential**		
					U	A	D	U	A	D
Ecomix	7.6 (7-9)	8.0 (7-9)	8.2 (7-9)	8.2 (7-9)	0	80	20	0	80	20
Greenfast	6.4 (4-8)	7.0 (4-8)	6.8 (5-8)	7.7 (5-9)	20	60	20	40	60	0
Tall fescues	8.4 (6-10)	7.8 (6-9)	7.2 (6-9)	7.7 (6-9)	20	60	20	80	20	0
Greenfast.+ Tall fescues	8.0 (5-10)	8.0 (5-10)	8.2 (6-10)	8.2 (7-10)	0	60	40	0	60	40

Response of landscape students.

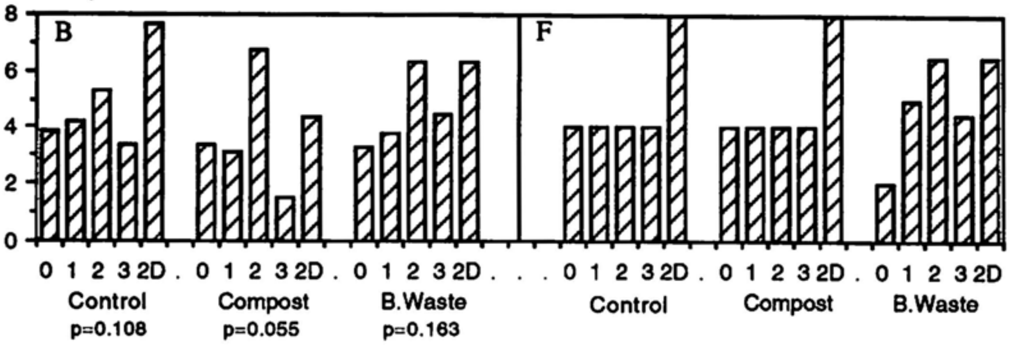
Plot	Average Value Out of 10 With Range ( )				% Responded					
	Color	Density	Overall	Height	Commercial			Residential		
					U	A	D	U	A	D
Ecomix	7.3 (6-9)	7.8 (6-10)	7.3 (5-9)	7.2 (5-10)	0	60	40	0	60	40
Greenfast	7.7 (6-9)	7.7 (6-8)	7.4 (6-8)	7.2 (5-9)	0	90	10	0	70	30
Tall fescues	7.5 (6-9)	7.3 (6-8)	6.4 (4-8)	6.8 (5-9)	10	90	0	20	70	10
Greenfast.+ Tall fescues	7.4 (6-10)	7.4 (6-9)	7.2 (5-9)	7.0 (5-9)	10	40	50	10	50	40

Appendix 3. Greenness rankings for individual main plots.

Oct.6/92



May 17/93



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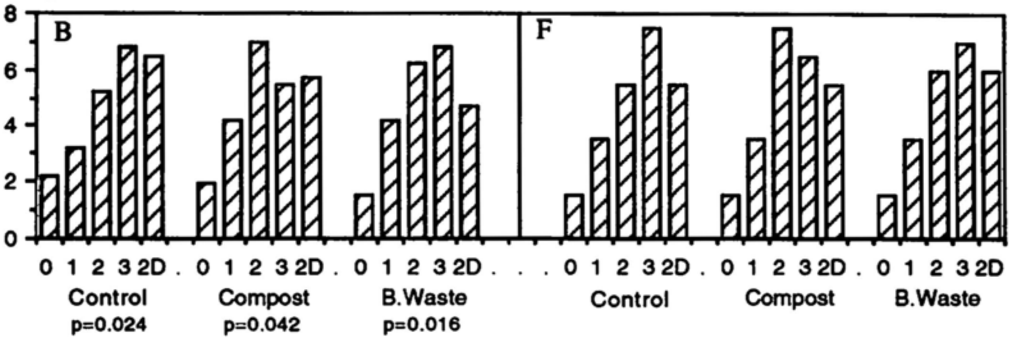

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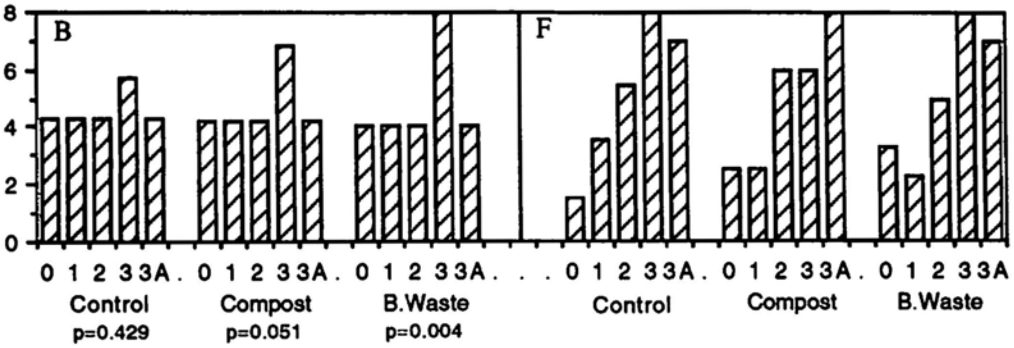

Figure 3.1. Greenness ranking of each subplot for each main plot on the B and F fields in 1992 and 1993.

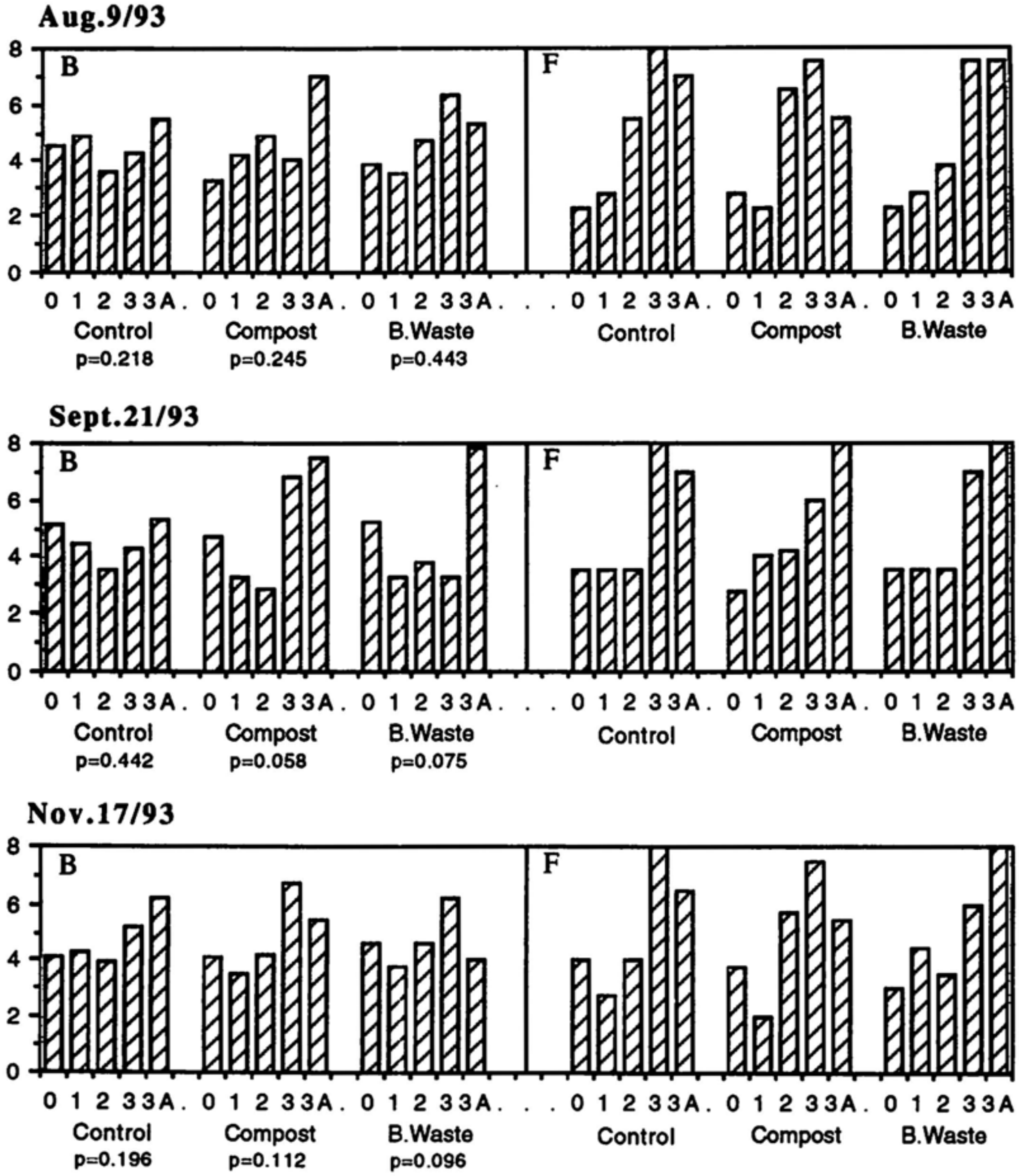

Figure 3.1. Concluded.

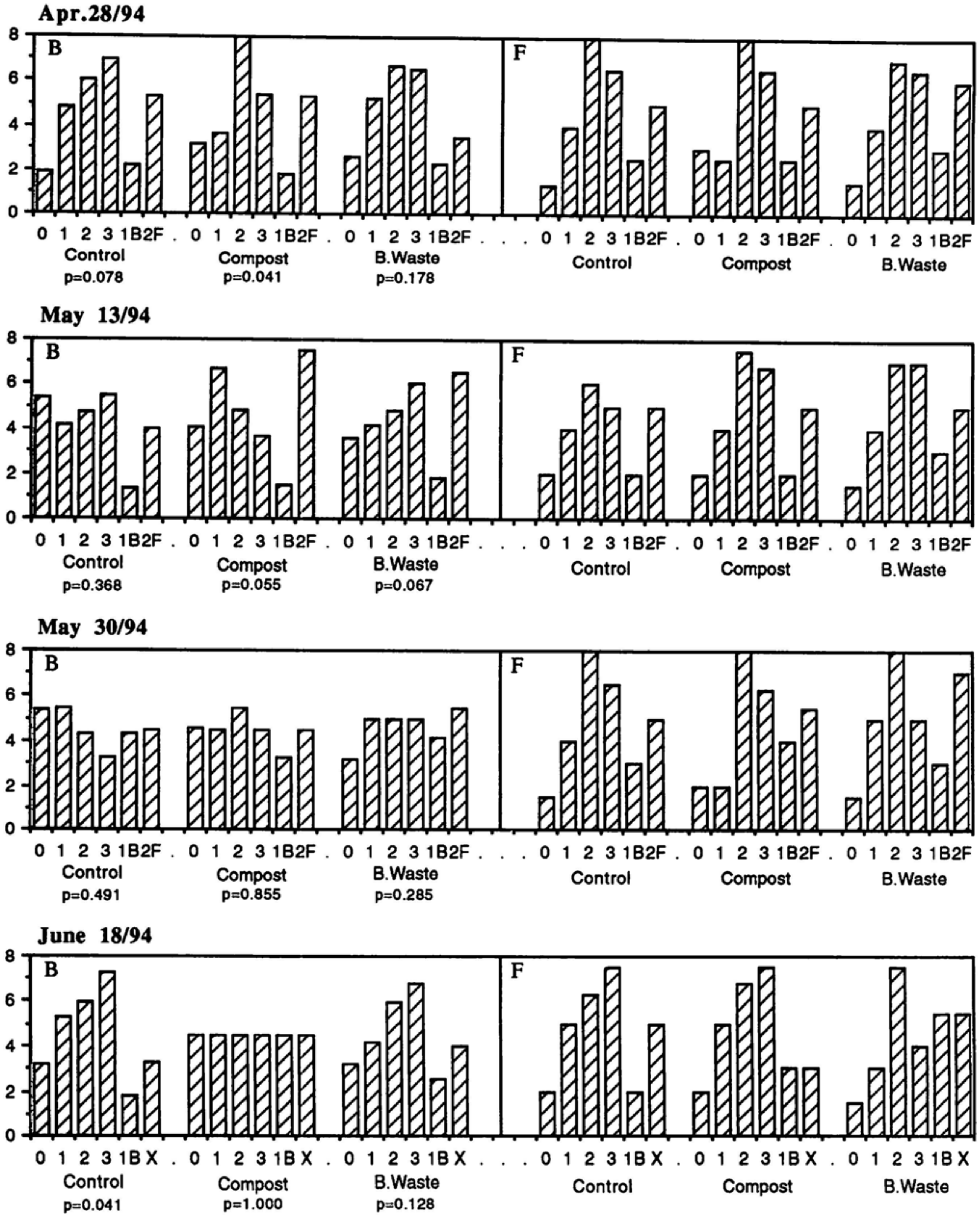

Figure 3.2. Greenness ranking of each subplot for each main plot on the B and F fields in 1994.

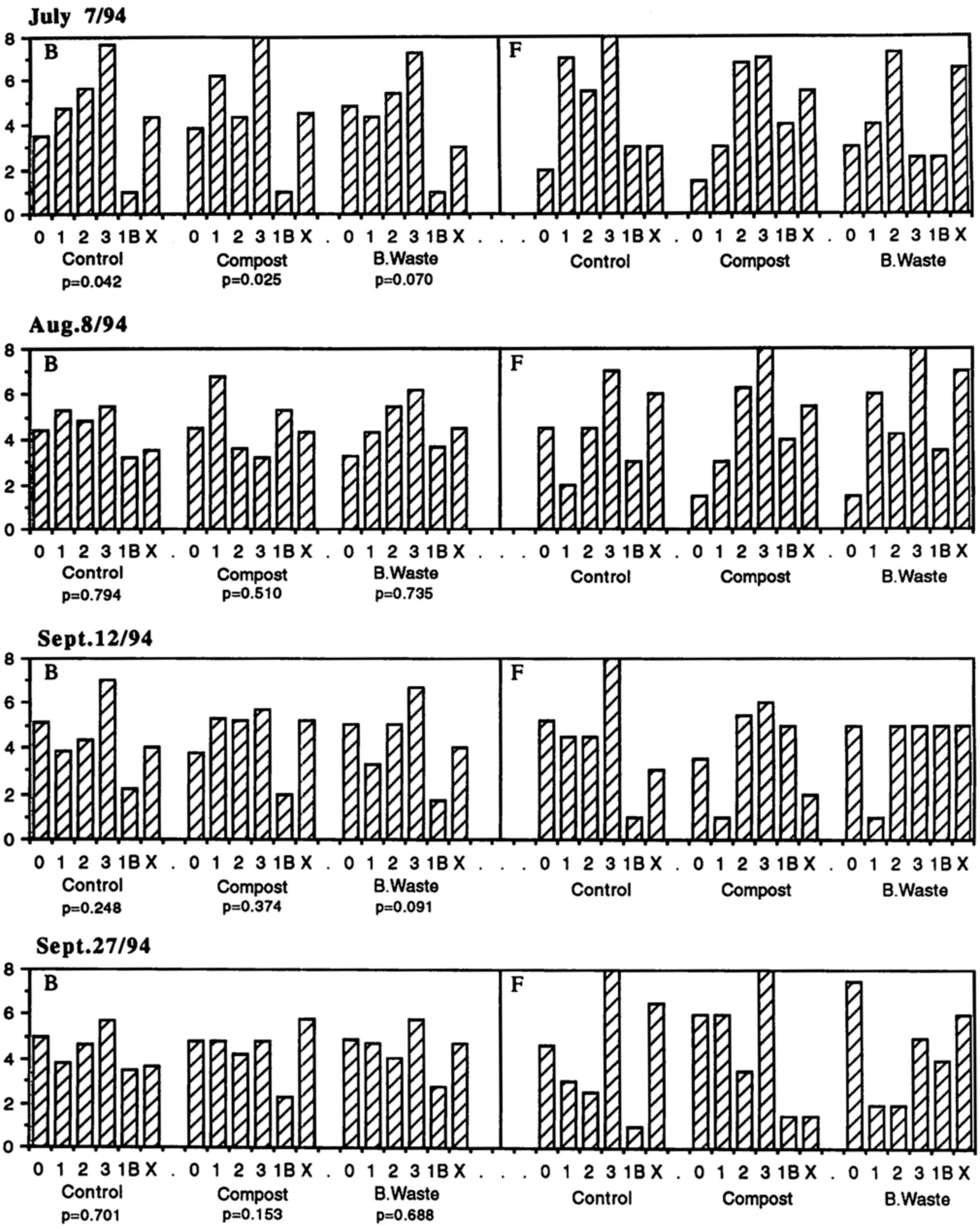

Figure 3.2. Continued.

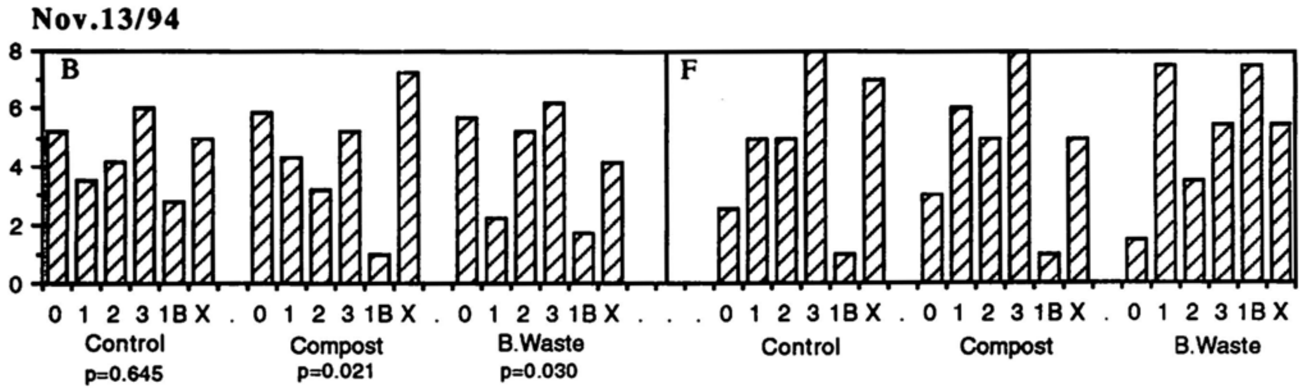

Figure 3.2. Concluded.

Appendix 4. Experiments with rock-P.

Excess phosphorus (P) is a major cause of degradation of lakes through the process of eutrophication. High P levels stimulate blooms of planktonic algae, turning the water green and murky. When these die, they sink to the bottom where they consume oxygen, which stimulates more release of P from sediments, and kills fish. Water plants in shallow lakes and around the edges are also stimulated by excess P.

Surface runoff of P fertilizer and soluble organic P in manures from farms has been a major contributor to deterioration of the Great Lakes; it is being dealt with by a variety of measures, notably maintaining more cover on soil in winter to prevent runoff and erosion. Many lakes in urban areas are deteriorating in spite of implementing mitigative measures, such as eliminating septic treatment of sewage, creation of buffer zones, etc. A study of First Lake, Lower Sackville, N.S. was commissioned to identify causes of lake deterioration of this popular recreational resource. It was concluded that inputs of organic refuse, dog feces (contributing to bacterial contamination; also P) and fertilizers were involved. That lake is particularly sensitive because the storm sewer system, serving approximately 6000 residents, empties directly into the lake (Loucks, et.al. 1994).

One component to an "organic" solution of this problem might be to use less soluble forms of P as fertilizers on turfs adjacent to the lake. Superphosphate fertilizer is prepared from rock phosphate (rock-P), by treating it with sulfuric acid to convert the more insoluble rock P to simpler, more soluble P compounds. Some plants carry out this process naturally by acidifying the rhizosphere (soil around roots) as they are taking up nutrients, which solubilizes the P. The P is immediately taken up. Legumes acidify the rhizosphere when they are utilizing nitrogen gas (from the soil air), but not when growing on nitrate. Phosphate mobilized by the legumes can be turned over to grasses when the tissues decompose.

Thus, we hypothesized that a mulch mowed, clover based turf fertilized with rock P would have adequate P, with very little potential for P losses to aquatic systems.

Methods

To test this hypothesis, we set up the following treatments on subplots in the Control main plots in 1992:

1. No rock-P, Grass
2. Rock P, Grass
3. No rock-P, Grass/Clover
4. Rock-P, Grass/Clover

Plots were 9 m^2 or larger. Rock P of the "hard" type (30% P_2O_5), obtained from Island Fertilizers, Prince Edward Island, was applied at a rate of 166 g m^{-2}, to give a P loading of 500 kg P_2O_5 ha^{-1}. Observations on turf and soil in these plots followed methodologies applied in other parts of this study. They included observations of chlorophyll, ranking for greenness, and observations on diseases.

Results

- Clover appeared in all plots in June, 1993, but was more abundant in the clover seeded plots (estimated cover was 40-46% B field; 12-43% F field) than in those not seeded with clover (17-28% B field, 0-8.5% F field).

- In 1994 on the B field, clover frequency in July was 98.5-100%; on the F field, it was less than 30% in plots not seeded with clover and was 100% in plots seeded with clover.

The invasion of non-seeded plots by clover meant that we did not have a categorical clover treatment (clover either present or absent), however, within the minus clover plots, we restricted sampling to areas where there was little or no clover.

- Measurements of chlorophyll in 1992 (Fig. 4.1) suggested there had been some response of turf to rock P on the B field, but not on the F field.

- On July 14, 1993 and July 14, 1994, clover but not rock-P increased chlorophyll SPAD values (Fig. 4.1). Clover chlorophyll was also measured in 1994; it was not affected by the treatments (data not shown). Other variables measured in 1993 were thatch and root depth (June 14), pH, EC and nitrate (mid-summer, 1993) rankings of greenness (June, July, August); none showed any significant or suggestive trends of differences between treatments (data not shown).

- In 1994, compression resistance, which is proportional to turf biomass or verdure (Appendix 6) and frequency of red thread were observed, and likewise showed no significant or suggestive trends of differences between treatments.

On August 10, 1994, samples of grass and clover were taken from each of the subplots and analyzed for macronutrients and cadmium.

- There was no evidence of P enrichment of grass or clover on the +RP plots. Grass N% was higher in the +clover plots than in the -clover plots and the effect was much stronger for the F field than for the B field (Table 4.1). Cadmium was determined because an analysis of the rock-P showed a significant level of Cd. No Cd was detected in any of the vegetation samples (limit of detection 1 ppm Cd).

Soil samples were taken in the fall of 1994; these were combined for each Block into -rock P and + rock P samples (Table 4.2).

- P levels did not differ significantly for the B field, although the value for the +RP plots was numerically higher than that for the -RP plots. pH of the +RP plots was higher than that of the -RP plots as was Ca. On the F field, Ca was elevated in +RP plots, but not in the -RP plots. The increased Ca and pH can be attributed to dissolution of the rock-P which consists of calcium phosphate minerals.

There is little if any evidence from these experiments of a substantial P-fertilizing effect of rock-P in these applications. The chlorophyll data of the first year were suggestive of a P-fertilizing effect, and as would be expected, the effect was seen on the B field which had an acidic pH but not on the F field. There was slight enrichment of soil by P at the end of the third year. It was not possible to tell whether it affected plant P.

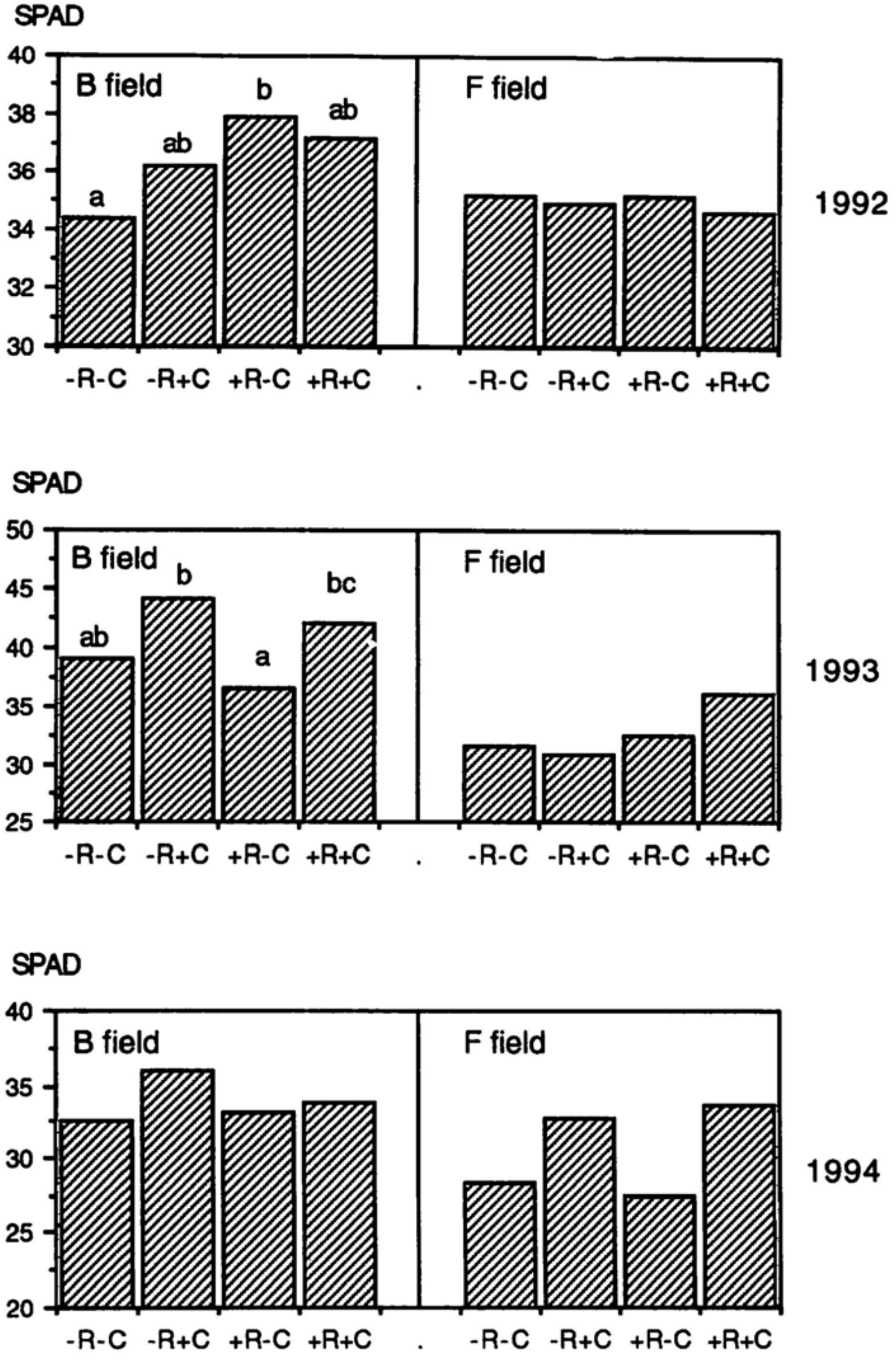

Figure 4.1. Chlorophyll values in rock-P experiment on Aug. 19, 1992, July 14, 1993, and July 14, 1994. For the B field, bars not sharing letters are significantly different ($\alpha = 0.05$). In 1994, there were no significant differences between individual treatments, however, plus and minus clover treatments (with or without rock-P) differ at $\alpha = 0.10$.

Table 4.1. Nitrogen, P, and Ca in plant tissues in plus/minus rock-P plots in August, 1994.

Variable	+clover: +RP	+clover: -RP	-clover: +RP	-clover: -RP
B field				
Grass N%	2.71	2.81	2.70	2.47
Grass P%	0.44	0.42	0.42	0.44
Grass Ca%	0.61	0.50	0.71	0.58
Clover N%	4.31	4.50		
Clover P%	0.53	0.48		
Clover Ca%	0.83	1.08		
F field				
Grass N%	2.54	2.39	1.74	1.78
Grass P%	0.51	0.50	0.50	0.51
Grass Ca%	0.74	0.93	0.74	0.75
Clover N%	4.10	3.99		
Clover P%	0.46	0.48		
Clover Ca%	0.95	0.84		

Table 4.2. Soil P, Ca, and pH in plus/minus rock-P plots in August, 1994.

Field	Soil P (ppm)		Soil Ca (ppm)		Soil pH	
	-RP	*+RP*	*-RP*	*+RP*	*-RP*	*+RP*
B field	21.3	27.3	873	1173	5.9	6.2
F field	98.0	110.0	1283	1316	6.9	6.6

Appendix 5. Testing of humates and different seed mixes on chronically poor turf area.

The southwest corner of the B field exhibited very poor growth of grass after the first season, appearing nutrient and water stressed (Photos 10 b,c). A profile to 50 cm showed no unusual features (e.g. tree roots). We had noted growth of white fungal mycelium in the area after it was rotovated in May, 1992. The tall fescue plus clover plot for Block 2 was located adjacent to this area, and did not exhibit these symptoms, suggesting possibly that tall fescues might perform better in the area than Ecomix. It was also suggested that we try an application of commercial humates to the soil when we renovated.

Methods

In mid-July 1993, the area was rotovated, and allowed to stay fallow for one month. A contact, fatty acid herbicide (Topgun) was used to kill grass that regrew after rotovating. On August 17 five pairs of plots were established, each plot of 2.5 x 2 m dimensions. One plot in each pair received humates (Humate Canada Ltd., Midnapore, Alberta; 0-0-3-15; N-P-K-humic and fulvic acids) at a rate of 1.3 kg m^{-2}. Organofertilizer (Seagreen) was applied at a rate of 3 lbs N per 1000 sq ft. The humates and organofertilizer were worked in with a shovel followed by rotovating. Assuming they were distributed to 20 cm, this humate application was equivalent to 6.5 kg m^{-3}. The suggested rate of application in construction of new turf is 3 lb per cubic yard, which is about 1/4 of the amount we used. Each pair of plots was seeded with a particular grass mixture. Thus in summary, the different treatments were:

(1) Greenfast + 35% tall fescues plus humate.
(2) Greenfast + 35% tall fescues minus humate.
(3) Ecomix plus humate.
(4) Ecomix minus humate.
(5) Tall fescues plus humate.
(6) Tall fescues minus humate.

Results

- There was good growth in the fall on all plots (Photo 10d), and no consistent difference between plus and minus humates plots in each pair in regard to color or germination. By mid-summer 1994, however, the area again deteriorated to the condition observed before it was renovated, and none of the treatments looked better than any others.

- Soil samples were taken from the plots in the fall of 1994, and composite samples of the plus and minus humate plots analyzed (Table 5.1). There was very little difference in the values for the different variables between plus and minus humates plots.

We conclude that neither the grass mixes, or humates, were able to ameliorate the condition in this part of the field.

Based on their chemical composition, Stevenson (1986)[1] concluded that commercial humates could not have any substantial benefits on soil properties when applied at more economic rates (500 kg ha^{-1} versus 13000 in this case) and that there was little evidence to indicate that they increase the efficiency of nutrient use by crops. At 15% humates, the application we used would raise the soil organic matter by approximately 0.1%. (6.5 kg humates applied per cubic meter of soil; assuming a bulk density of 0.8, that is 6.5 kg humates to 1040 kg soil). The soil data show a decline of 0.3%, which is within the probable margin of error. The K application corresponds to 133 ppm K. There was no indication of any significant differences in available K between the plus and minus humate plots.

Table 5.1. Soil analysis data from plus and minus humate plots in fall of 1994.

	OM *%*	**pH**	**P** *ppm*	**K** *ppm*	**Mg** *ppm*	**Ca** *ppm*	**CEC**	**K** *%*	**Mg** *%*	**Ca** *%*	**H** *%*
+H	5.3	5.2	17	72	108	472	14.2	1.3	6.3	16.6	75.8
-H	5.6	5.1	26	73	98	467	15.3	1.2	5.3	15.2	78.2

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[1] Stevenson (1986) defines commercial humates as "oxidized lignites, or products derived from them. Oxidized lignite is an earthy, medium-brown, coal-like substance associated with lignitic outcrops. The material typically occurs at shallow depths, overlying or grading into the harder and more compact lignite, a type of soft coal. A unique feature of oxidized lignites is their unusually high content of humic acids, of the order of 30 to 60% of the material mined".

Appendix 6. Compression measurements.

We tested our own, simplified version of the "disc meter" method (Castle, 1976) for measuring forage biomass as a method for measuring turf biomass at The Oaks. This method is based on the concept that the greater the forage biomass, the more resistance it will exert to compression. Compression is measured by lowering a platform onto the surface of the vegetation and measuring height above the soil. The method is calibrated by measuring compression and biomass on a subset of samples and calculating conversion factors. The prime advantages of the method are its ease and speed of use, and the non-destructive nature of the measurement.

Methods

Our method consisted of lowering a book (23.5 x 30.5 x 1.9 cm linear dimensions and 1035 grams weight) carefully onto the turf to the point that there seemed to be some resistance to free fall, releasing it and measuring the height of the book above the soil. This value is referred to as "compression resistance" or compression for short. Height was taken as the average of the two heights measured at the midpoint of each of the 23.5 cm edges of the book. This particular book was chosen after testing a number of them for replicability of measurements and discrimination of differences between turf of high and low verdure.

Compression resistance and biomass measurements were made at seven sites on the B field selected to encompass a wide range turf density. These measurements were made between 1400 and 1500 hours on a sunny day (July 9, 1993); the turf had been irrigated in the morning and mowed three days previously. At each site, three measurements of compression resistance were made within a surface area of 1 x 1 m. Turf was cut with clippers at 1 cm height as for the biomass, taking three swaths at each stand at 1 cm height. Samples were weighed fresh and after drying.

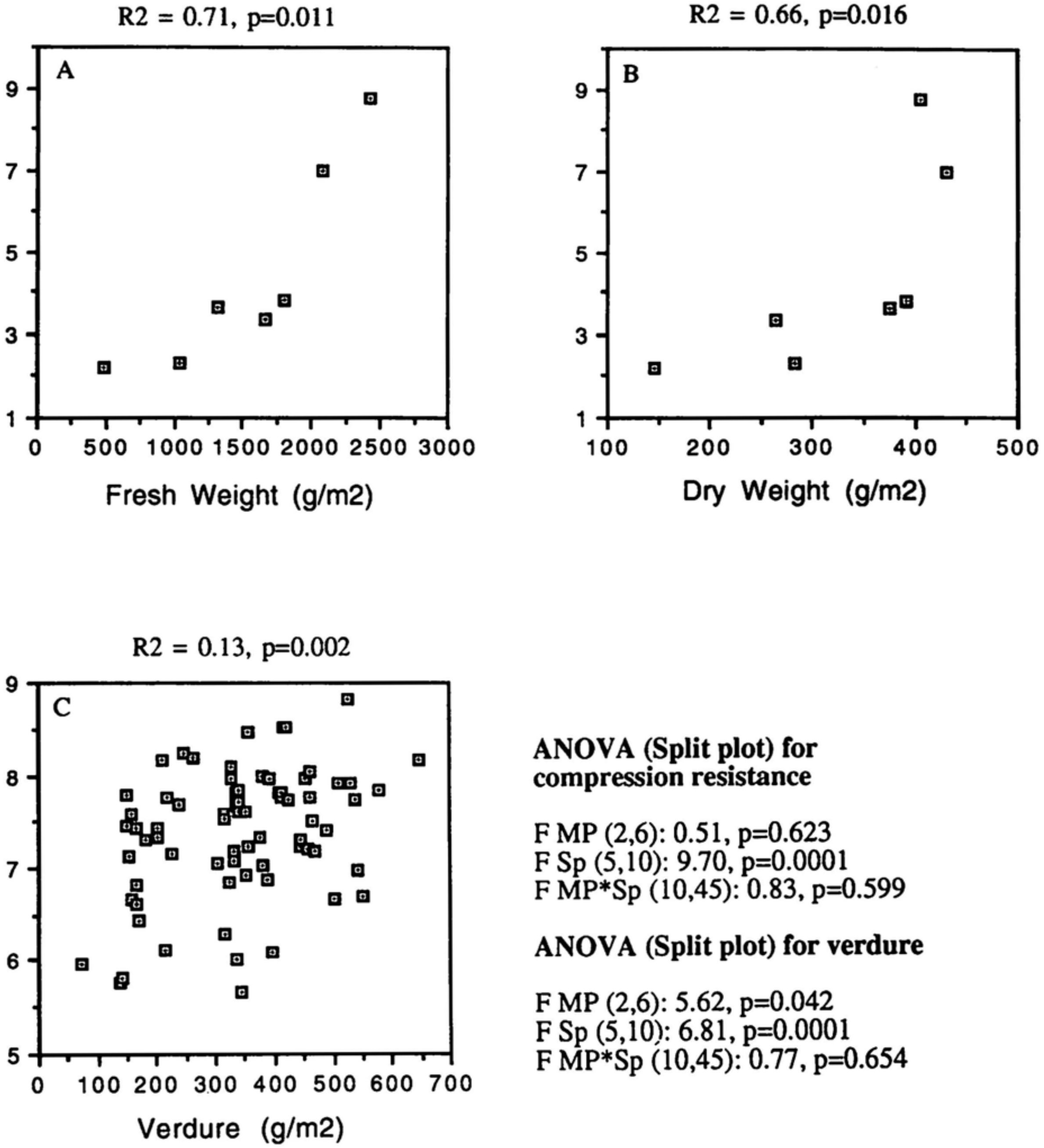
Compression data were obtained following these measurements (1500-1700 hr, July 9) on the same fertility plots in which biomass was measured the following week (July 13-14, 1993). One compression reading was taken at the center of each subplot.

Results

- There were high R^2 values for correlations of compression (resistance) with fresh and dry weight; values for the latter being slightly lower (Figure 6.1). Values were much lower for the fertility plot data. ANOVA's were run on both sets of fertility data for both verdure and compression resistance. The compression resistance observations showed significant differences in the same direction indicated by the verdure data. However, there were no significant main plot effects evident for the compression data, while there were for the verdure data. Also, the large differences in verdure between the F and B field were not seen for the compression resistance data.

We interpret these data as follows. The high R^2 values for the regressions of compression resistance on fresh and dry biomass weights are consistent with the underlying assumptions concerning the technique. It is sensible that the R^2 values are lower for the dry weight data, as turgidity due to osmotic factors would be expected to contribute significantly to compression resistance and variation in this factor would be reflected in the fresh but not in the dry biomass weights. Other data suggested there were differences in the water status of the turfgrass associated with Block differences and main plot differences (Section III.1I), which could account for the insensitivity of the compression resistance values to main plot differences and to the large differences in verdure between the B and F fields.

We conclude that the compression resistance measurements probably provide values that relate closely to verdure when water status does not vary substantially, however, when it does (e.g. between treatments or between different measurements made at different times of day), then compression resistance measurements are not likely to be closely related to verdure.



ANOVA (Split plot) for compression resistance

F MP (2,6): 0.51, p=0.623
F Sp (5,10): 9.70, p=0.0001
F MP*Sp (10,45): 0.83, p=0.599

ANOVA (Split plot) for verdure

F MP (2,6): 5.62, p=0.042
F Sp (5,10): 6.81, p=0.0001
F MP*Sp (10,45): 0.77, p=0.654

Figure 6.1. (A) Compression resistance of turf plotted against fresh weights of turf for seven sites and, (B) against the dry weight for the same sites. (C) Compression resistance of fertility plots measured on July 9, 1993 (all Blocks) versus verdure measured on July 14-15, 1993.