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WATER IN THE 21ST CENTURY: CONSERVATION, DEMAND, AND SUPPLY
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CROP WATER MANAGEMENT THROUGH SOIL IMPROVEMENT

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ABSTRACT: Since 1991, methods for improving potato production in Aroostook County, Maine by soil enhancement have been investigated. In a recent experiment, the main objective has been to better manage available water resources to ensure that adequate moisture will be available to the crop throughout the growing season. The primary target has been soil organic matter improvement and the main mechanism has been organic soil amendment additions. Results to date indicate potato tuber yield improvements have been achieved, although some disease problems have been identified. Soil physical and chemical properties (moisture retention, bulk density, macro-nutrients, micro-nutrients, aeration, organic matter, etc.) have been evaluated to determine the source or sources of these improvements. Changes in individual soil physical properties when present have been modest, indicating that benefits are derived from nutritional factors and/or possible interactions among the above factors rather than any specific factor. This also indicates that the improvements may be short-term.
KEY TERMS: Aroostook County; potatoes; crop available water; compost.

INTRODUCTION

Maine, part of the humid northeast United States, often experiences drought conditions during critical periods in the potato growing season. A significant portion of the State's economy is derived from the potato industry, thus it is imperative that soil moisture be maintained throughout the season to ensure that a high yielding, high quality, marketable crop will be produced. Although irrigation is an obvious solution, it is not readily accessible to all growers due to limited financial and water resources.

Use of organic soil amendments in agricultural applications is being studied extensively in a variety of field experiments at the Aroostook Farm Research Center in Presque Isle, Maine. One project is investigating means of managing crop water availability. One component of this work evaluates the benefits of supplemental water application for four regionally important potato varieties. A second component, the focus of this article, involves supplemental moisture applications superimposed on four rotation/soil management treatments: oat rotation, oat rotation with soil amendment, green manure rotation, and green

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manure rotation with soil amendment. The soil amendment is locally produced compost, made from cull potatoes, combined with beef manure.

Soil Benefits of Compost Use

Many benefits of compost application have been documented. Soil microflora and microfauna diversity are enhanced by compost application. Diversity is indicative of a healthy ecosystem since diseases and pathogens are suppressed. Added organic matter improves cation exchange capacity. Therefore, a greater proportion of applied chemicals (nutrients, pesticides, etc.) is held in the soil is readily available for plant uptake. There are soil structural improvements (through aggregation) which are responsible for better aeration and permeability (infiltration). Improved infiltration can reduce runoff and erosion, and consequently surface water pollution. Most importantly, moisture retention is improved. This means that more moisture is available to the crop and soluble chemicals are not as easily leached.

Waste Management Benefits

The focus on composting has intensified tremendously in the past decade. Limited landfill volume, high waste disposal (tipping) fees, and the desire to treat residual material as a resource rather than a waste are the driving forces behind this emphasis. Recent events in Aroostook County have made it imperative that regional composting operations be established. A major concern is that improperly disposed of cull and waste potatoes can become a source of inoculum for a catastrophic potato fungus. Because of limited disposal options, these potatoes must be composted.

METHODS AND MATERIALS

Experimental Design and Site Description

This recently established project investigates three supplemental water application rates superimposed on the four previously described soil management strategies. The amended plots receive 22 t/ha of potato cull compost and 44.9 t/ha of cow manure. Plots are further split by low and high N fertilizer rates; due to excessive research traffic in the plots and subsequent crop damage, this subtreatment will be dropped from the experiment in the future. The general irrigation treatments are rain-fed, moderate and optimum. These irrigation levels are based upon a strategy of maintaining tensiometer readings within certain ranges, 70 - 80 kPa tension for moderate and 50 - 60 kPa for optimum. Optimum irrigation scheduling Practices are not well established for this area and these ranges represent our collective best estimates.

The site is composed of two experimental series: a potato series and a rotation crop series, which rotate annually. The experiment is a split plot, randomized complete block design with irrigation levels as the main treatments and rotation and amendment practices as subtreatments.

Soils in these plots are Caribou gravelly loams (fine-loamy, mixed, frigid, Typic Haplorthods). There may be pockets of Conant soils, which are similar to Caribou but more poorly drained. These soil types are

common to this farm and are predominant throughout northeastern Aroostook County. Organic matter levels are low (approximately 2.5 - 2.8 percent by weight) and cannot be improved or even maintained by normal agronomic practices. The soil was heavily cropped, mostly in potatoes, prior to establishing this experiment. Many farms in this area are experiencing similar soil problems.

Compost and Manure Analyses

The results of chemical analyses of the soil amendments, performed by the Maine Soil Testing Service at the University of Maine, are presented in Table 1 below. These materials are poor sources of N fertilization, but are good sources of micronutrients, especially boron. Potential loading problems may exist for phosphorus and potassium, as well as calcium and magnesium. Metals are well below accepted limits.

Table 1. Compost and Manure Analysis by Growing Season.

Organic Amendment Characteristic		---Analytical Results by Growing Season--- 1991	1992	1993	1994
Waste Potato Compost (d.w. basis):					
pH		7.6	7.46	8.72	8.0
Water	%	57.9	86.2	59.0	71.1
Total Nitrogen	%	0.51	0.56	0.76	1.49
Ammonium Nitrogen	%	0.11	0.04	0.05	0.08
Potassium	mg/kg	1967	4292	6335	11500
Phosphorus	"	1970	3601	1585	5370
Calcium	"	7620	4534	7655	9330
Magnesium	"	4307	-	3780	4380
Cadmium	"	0.6	-	1.2	1.3
Copper	"	22	-	20.5	30
Zinc	"	79	-	119.5	122
Boron	"	-	-	42	44
Beef/Dairy Manure (f.w. basis):					
pH		-	-	8.48	8.3
Water	%	42.2	65.3	68.0	71.0
Total Nitrogen	%	0.46	0.70	0.45	0.53
Ammonium Nitrogen	%	0.09	0.13	0.12	0.19
Potassium	mg/kg	1500	2733	2885	1550
Phosphorus	"	2367	2633	1385	1430
Calcium	"	-	-	5230	2590
Magnesium	"	-	-	2010	1220
Cadmium	"	-	-	-	-
Copper	"	-	-	6.8	6.2
Zinc	"	-	-	35.2	23.2
Boron	"	-	-	12	5.6

RESULTS AND DISCUSSION

Water Use

The amount of water received by the potato crop during the growing season (early June to early September) is presented below in Figure 1.

The main treatments (irrigation) changed from 1993 to 1994. In year one, the treatments were rainfed (control), moderate irrigation, and excessive irrigation. In the second year, the treatments were modified to rainfed, moderate and optimum. This change was in response to a shift of focus from soil and soil moisture interactions to crop physiological responses. During 1993, the excessive treatment also had a severely negative tuber quality impact. Although 500 mm of water (excessive treatment) is not necessarily a gross over-application of water, the timing of these applications was not appropriate for the crop water requirements at the time of application.

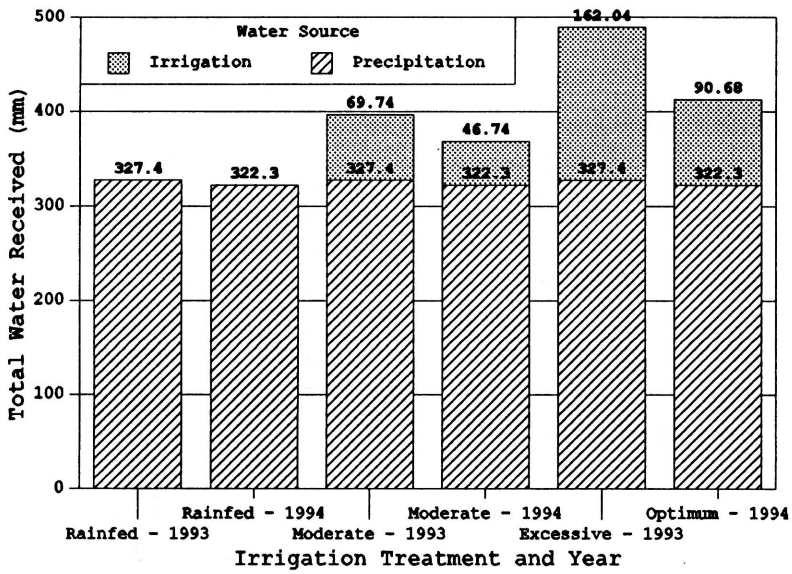

Figure 1. Water Received (June to September).

Potato Tuber Yield and Quality

Analysis of variance for 1993 indicated no significant effect of irrigation treatment on yield and a significant effect of soil amendment. For this reason, analyses of total yield, marketable yield and tuber rot were averaged across the three irrigation treatments. The results are presented in Figures 2 through 4. Total yield was significantly better for amended versus unamended plots. The improvements were not nearly so pronounced with regard to US#1 yield. This was especially true in 1993 when there was an unusually high level of tuber rot, due to poorly timed irrigation applications toward the end of the year. Because of reduced moisture consumption, soil moisture conditions were conducive to disease transmission. Substantial losses were incurred, especially in the excessive irrigation treatment. Rot losses were considerably lower in 1994 across all irrigation treatments.

Soil Properties

Bulk density and moisture retention were the soil properties of interest in this experiment. It was felt that these properties would

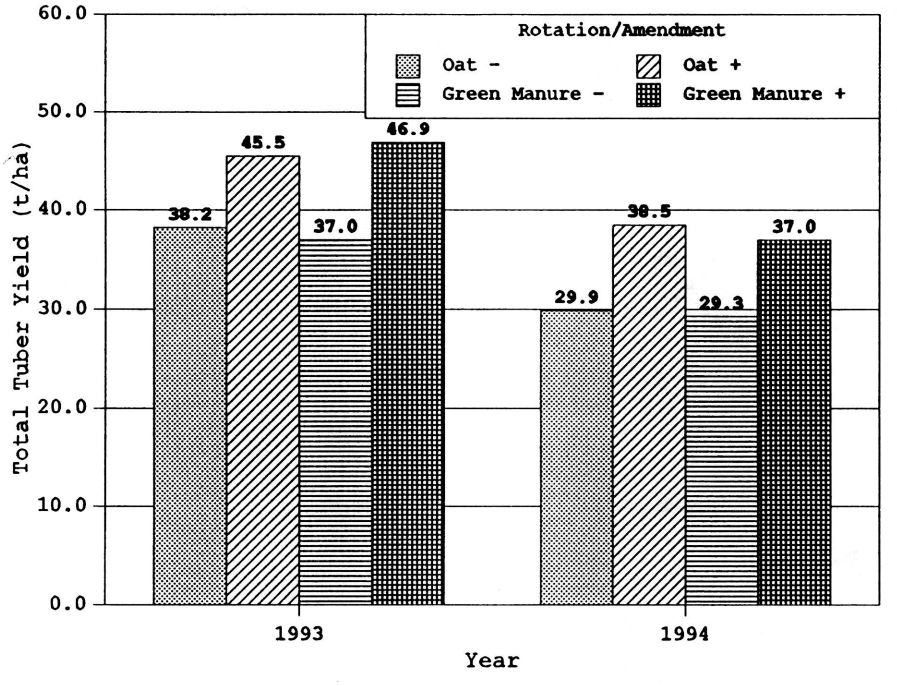

Figure 2. Total Tuber Yield Results.

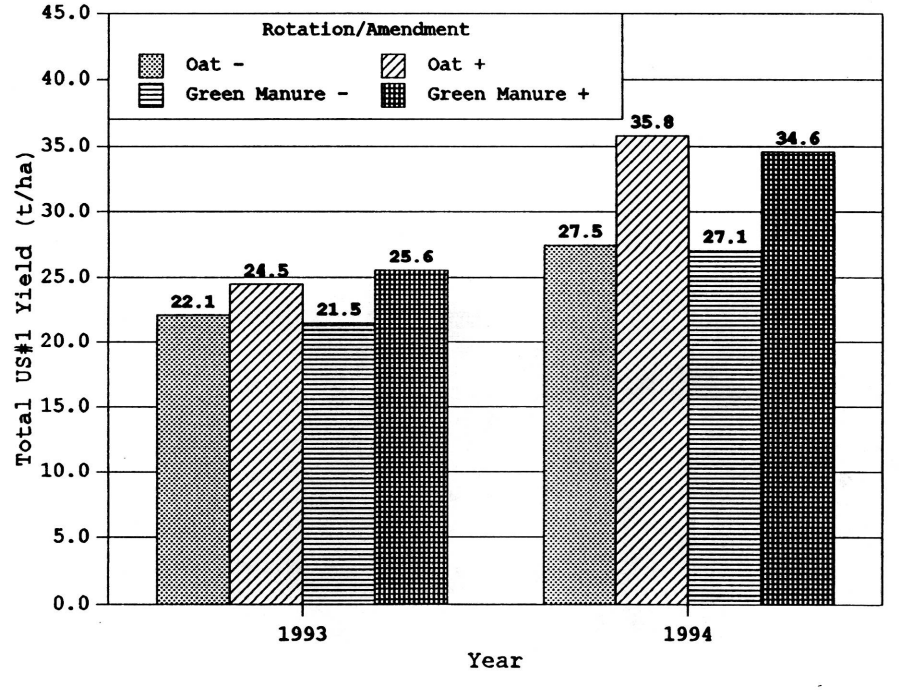

Figure 3. Total US#1 Yield (Less Rotten Tubers and Other *External Defects*) Results.

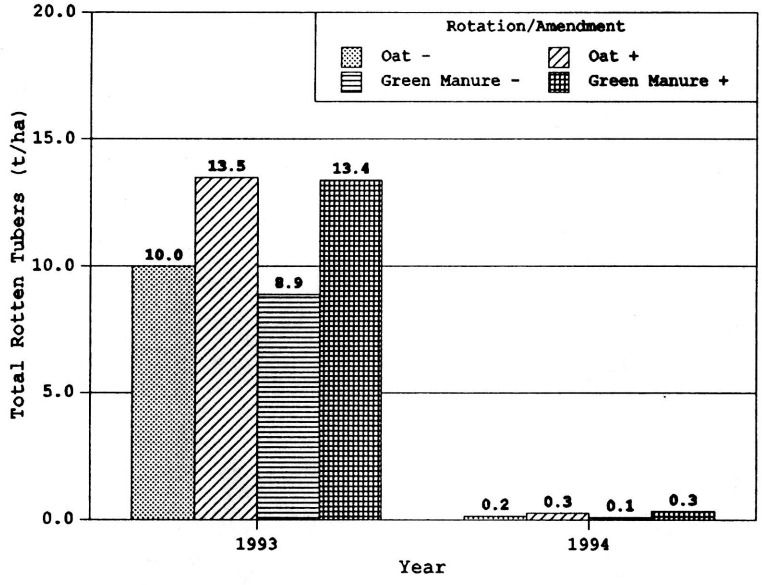

Figure 4. Total Rotten Tuber Results.

most likely be affected by organic matter addition. The possibility of moisture retention improvement is especially critical as this would most certainly improve the efficiency with which naturally available moisture was used.

Bulk Density

Soil bulk density was not significantly affected by organic matter addition (Figure 5). For three sampling dates, bulk density for amended

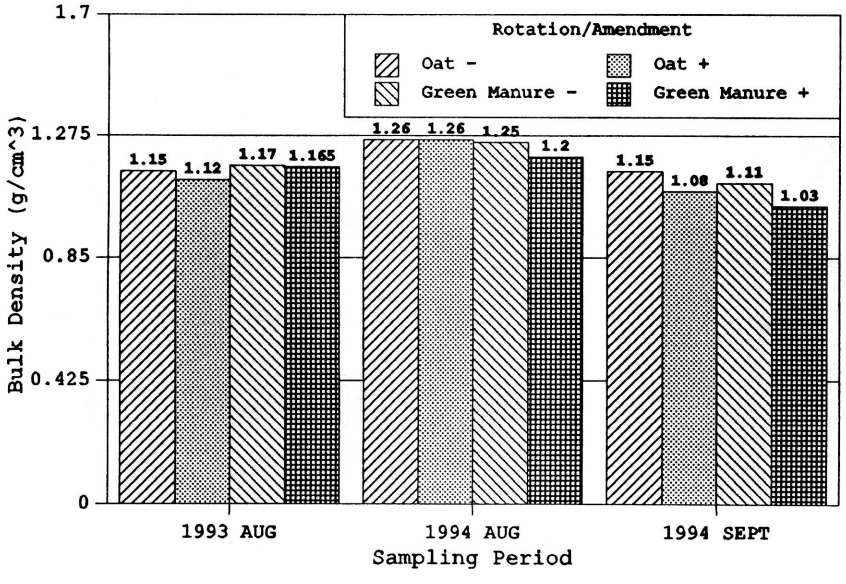

Figure 5. Bulk Density Analyses.

plots was the same or slightly lower than the unamended plots. These differences could be explained by natural variations in the soil.

Moisture Retention Curves

Results of pressure extraction tests on disturbed soil samples (particles > 2 mm removed) appear in Figures 6 and 7. These curves approximate the soil's drying curve and are representative of results for all irrigation treatments and blocks. These graphs indicate that amended soil have greater gross moisture content at a given pressure. Rotation crops had no apparent effect on moisture holding capacity. Net available moisture was not affected by any treatment. This would have been expressed by an increased slope between any two plate pressures.

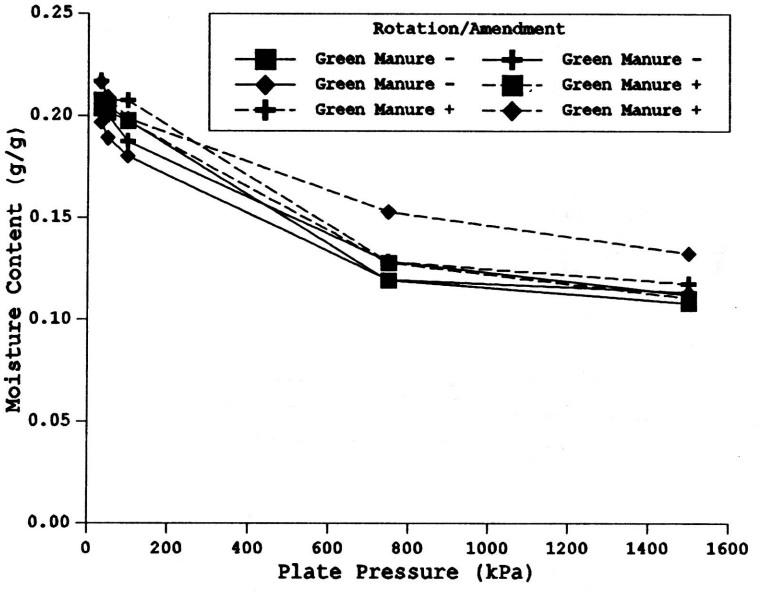

Figure 6. Amendment Effect on Soil Moisture Retention.

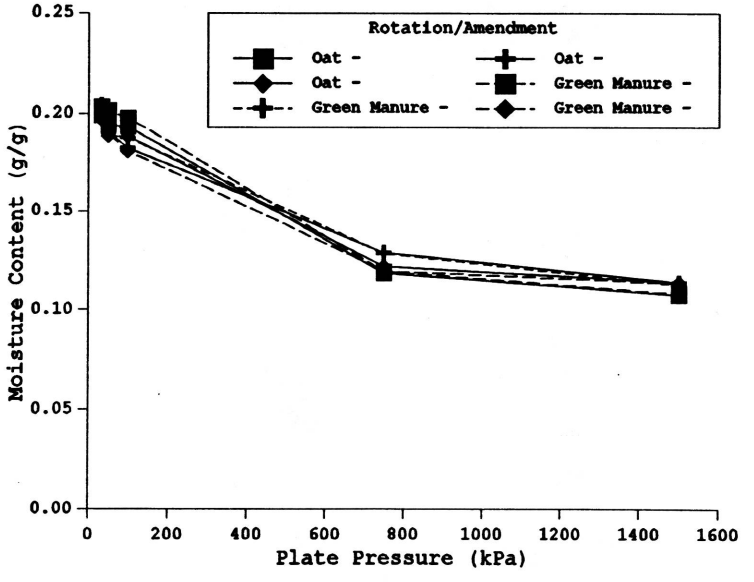

Figure 7. Rotation Crop Effect on Soil Moisture Retention.

CONCLUSIONS

Providing supplemental water by irrigation is a water management option that is not available to all farmers in the Aroostook County area. Available soil water can be better managed if soil moisture holding properties can be improved. Annual addition of cull potato compost and cow manure has been shown to improve potato yield and quality across three moisture management regimes.

Effects of soil amendment addition appear to be partially nutritional and possibly temporary, as changes in the measured soil physical properties are modest at best. Analysis of organic matter content and water stable aggregates may reveal other effects of the amendments. Related studies have shown increases in both characteristics. It is important that mechanisms to make these soil enhancements sustainable be identified. Possible solutions may include higher organic loading rates, more conservative crop rotation strategies, or some combination of conservation and enhancement practices.

If sustainable soil physical property improvements can be gained from soil management and improvement, water resources in general will benefit. Potato producers will have access to improved crop yield without exploitation of existing water supplies or the development of new supplies. Reduction in water lost due to surface runoff and subsurface drainage and leaching will lead to an improvement in water quality. Rates of contaminant transport will be reduced thereby allowing soluble chemicals to be used beneficially or to safely decompose.

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