Effect of Cropping and Fertilization on Soil Microflora in an Oily Waste Amended Loamy Sand

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Introduction

A field study to assess the impact of oily waste application on soil properties and crop production was conducted on a highly erodible, loamy sand near Richmound, SK between 1997 and 1999. The oily sludge from the CCRL Upgrader in Regina was applied to alleviate erosion and build soil organic matter thus improving soil quality while utilizing an industrial waste product. Fertilizer and cropping treatments were used to assess their impact on oily waste bioconversion. Oil-related fertilization has been reported to encourage microbial biodegradation of hydrocarbons thus speeding up reclamation and allowing cereal crop production to reach levels similar to the unoiled control within one year (Toogood et al. 1977). Microbial populations or activities have been used to evaluate hydrocarbon biodegradation and bioconversion to stable humus although they are not direct measurements of bioconversion (Bossert and Kosson 1997).

The objective of this portion of the study was to evaluate the effect of oily waste sludge, oil-related fertilization, cropping and crop type on various soil microbial populations and microbial activity over the course of the field study.

Materials and Methods

Field site preparation, cropping practice and treatment application as well as soil and oily waste characteristics were described previously (Hanson et al. 1999). In spring 1998, 48 of 96 plots were cropped to Kyle durum and Calibre oats (24 for each crop). In spring 1999, the other 48 plots were cropped to durum and oats.

Soil samples were collected to a depth of 10 cm in the plots within 24 h of oil incorporation (Time 0), at 3 w after incorporation, in spring and fall 1998 and again in spring and fall 1999. Samples were stored field moist at 0°C until they were mixed and sieved at room temperature (to ensure complete mixing) before the samples were returned to 0°C storage.

Different soil microbial populations were enumerated and C-mineralization was determined using the protocols described previously (Hanson et al. 1999).

Results and Discussion

Soil bacteria responded quickly to the oily waste amendment with increases of up to 300% after three weeks compared to levels found at Time 0 (Figure 1a). Bacterial populations in most treatments peaked by five months, which is earlier than was found in an earlier study with a heavy oil production waste sludge (Biederbeck et al. 1994). After 23 months, there were three distinct groups of treatments based on bacterial numbers. Oil with fertilizer (1%, F & 2%, F) resulted in approximately 3 x 10^8 bacteria/g soil while oil alone (1%, U & 2%, U) supported about half that number and the unoiled control was at 0.9 x 10^8 bacteria/g soil (Figure 1a). This clearly shows that with C-rich amendments fertilization is important for boosting populations of soil bacteria and possibly improving soil quality.

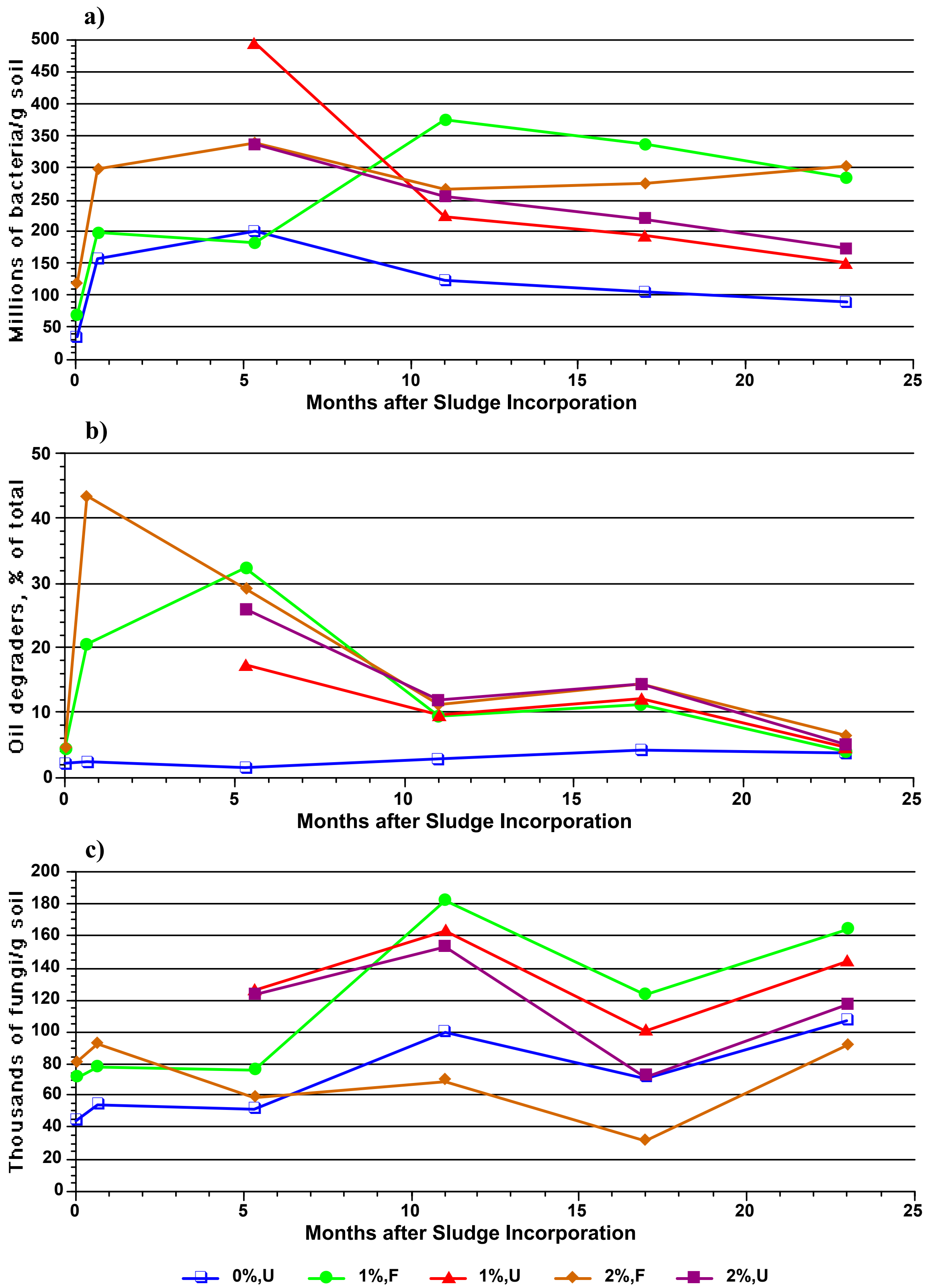

Figure 1. Response of a) bacteria, b) oil degraders, as % of total procaryote population, and c) filamentous fungi populations to the incorporation of an oily waste sludge in the top 10 cm of a loamy sand near Richmound, SK.

Microorganisms that degrade hydrocarbons are found in all soil environments and according to the literature they usually "constitute less than 1% of the total microbial communities" however, when oil is present the hydrocarbon-degrading populations can increase to 10% (Atlas 1995) or even higher (Pinholt et al. 1979). At Richmound, the percentage of oil-degrading procaryotes has dropped since peaking at 44% at the three week or spring 1998 sampling with all treatments being down to between 3 and 7% after 23 months (Figure 1b). This indicates that the vast majority of bacteria found in the general bacterial population do not utilize the oil directly as a C-source but may use intermediates of hydrocarbon degradation.

The effects of oil and fertilization on filamentous fungal populations were less pronounced than for the bacteria (Figure 1c). Oil with fertilizer produced significantly different numbers of fungi recovered, with 2%, F consistently lower than 1%, F after the three-week sampling. Furthermore, the combination of 2% oil with fertilizer seems to be detrimental to filamentous fungi as the resultant populations were slightly below those of the unoiled control (Figure 1c).

Cropping to either durum or oats, consistently supported higher populations of bacteria in 1999 than did fallow except for the 2% oil, unfertilized treatment that was cropped to durum (Figure 2a). Oil-related fertilization increased the bacterial populations in both crops and both rotation phases (Figure 2a). Actinomycete populations responded similarly to fertilization but not as consistently as bacteria or often to a lesser extent (Figure 2b). Cropping generally produced increases in actinomycetes compared to fallow and durum roots effected a distinct stimulation of the actinomycete population in comparison with the populations found under oats (Figure 2b).

Oil-degraders were very responsive to oil-related fertilization with large increases found in almost all treatments for both crops whether cropped or fallowed (Figure 2c). Oats did stimulate the numbers of oil-degraders more than durum in the majority of treatments (Figure 2c).

Filamentous fungi showed little response to cropping but were affected by crop type and durum, especially at the 1% oil level, boosted the population when compared to oats (Figure 3a). Fertilization responses were inconsistent among treatments for filamentous fungi and yeast, however cropping did increase yeast populations in most treatments (Figures 3a & b). Yeast populations responded much more to oats than to durum (Figure 3b).

These data suggest that those microorganisms that may be characterized as more metabolically active (bacteria and yeasts) were more responsive to oil incorporation and oil-related fertilization than the actinomycetes and filamentous fungi that may often be present in resting forms like spores.

The rate of C-mineralization was greatly increased by the addition of oil and fertilizer initially however after five months it was obvious that the oil-related fertilization was depressing respiration compared to treatment with oil alone (Figure 4). After 23 months, there are no significant differences in C-mineralization rate between oil treatments with or without fertilization although the number of bacteria were shown to be about double for the oiled and fertilized treatments compared to oiled only (Figure 1a). This indicates that although total respiration is the same per gram soil, on a respiration/microbial number basis the C-mineralization rate is still markedly lower for those treatments that received fertilizer. C-mineralization or respiration is often used as a measure of overall microbial activity, however, in this case it is also a measure of venting or excessive hydrocarbon degradation to

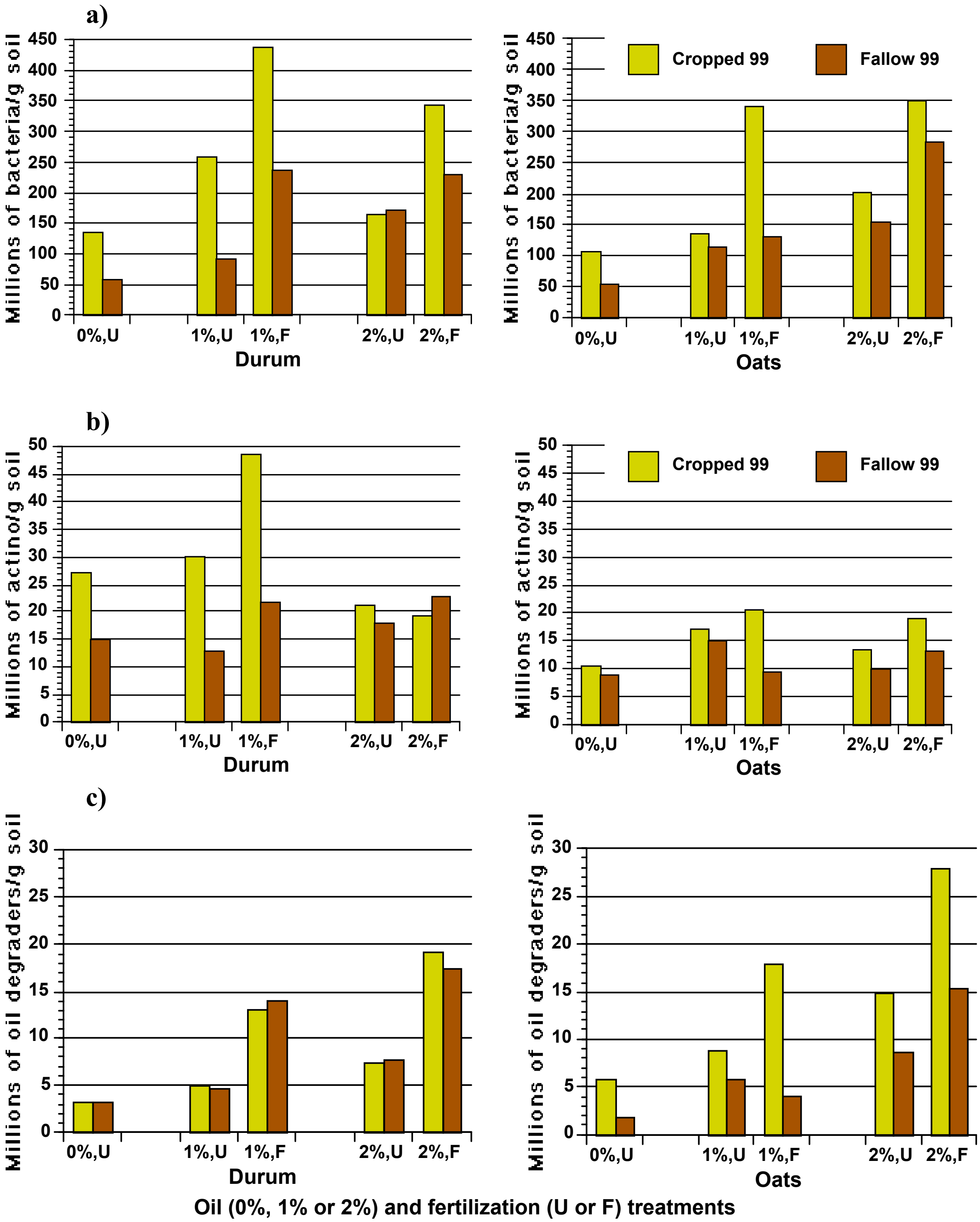

Figure 2. Response of a) bacteria, b) actinomycete, and c) procaryotic oil degrader populations in Fall of 1999 to cropping and fertilization after incorporation of an oily waste sludge in the top 10 cm of a loamy sand near Richmound, SK.

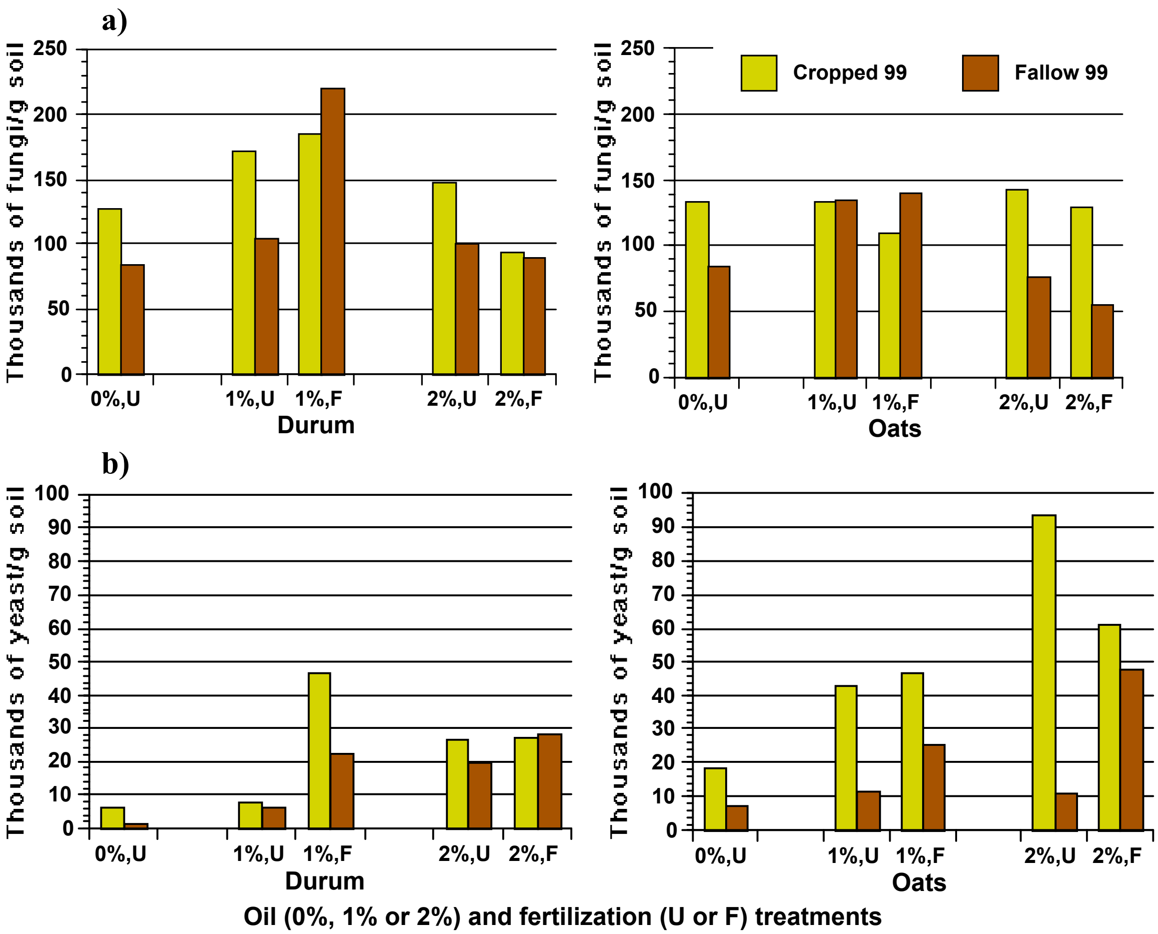

Figure 3. Response of a) filamentous fungi and b) yeast populations in Fall of 1999 to cropping and fertilization after incorporation of an oily waste sludge in the top 10 cm of a loamy sand near Richmound, SK.

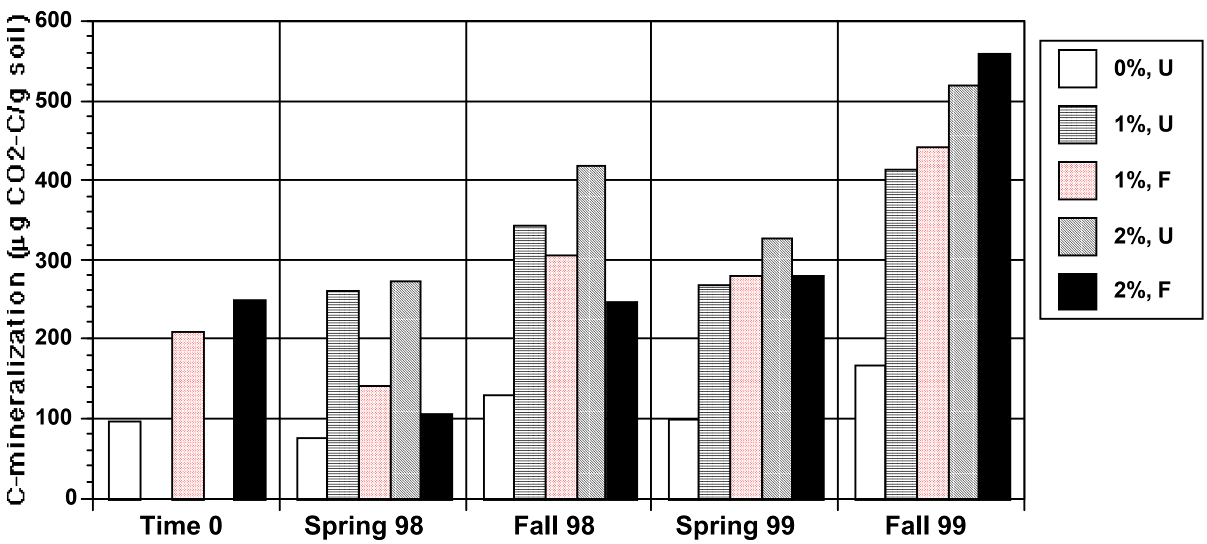

Figure 4. Response of microbial C-mineralization to the incorporation of an oily waste sludge in the top 10 cm of a loamy sand near Richmound, SK.

CO_2 gas. With the increased awareness of greenhouse gas effects on climate, the use of adequate fertilization for more efficient bioconversion of hydrocarbons to stable soil humus (sequestered C) is now being emphasized instead of venting.

Conclusions

1) Incorporation of oily waste sludge boosted most microbial populations relative to the unoiled control, however it increased bacteria > actinomycetes, and yeasts > filamentous fungi.

2) Oil-related fertilization increased microbial numbers in most treatments with population responses similar to above.

3) Cropping generally increased microbial populations due to beneficial root effects.

4) Oil degraders and yeasts were stimulated by oats, while actinomycetes and filamentous fungi were favoured by durum.

5) Oil-related fertilization decreased microbial respiration early in the study and rates are still relatively lower than in unfertilized treatments per microbial unit.

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Keywords:
oily waste; biodegradation; microbial populations; fertilization; crop effect.