Organic Solvent-Soluble Organic Matter from Soils Underlying Native Range and Crested Wheatgrass in Southeastern Alberta, Canada

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Abstract

Gas chromatographic patterns of organic solvent-soluble constituents present in alkaline hydrolysates of organic matter from soils underlying native range and crested wheatgrass were qualitatively, but not quantitatively similar. The peak at 222°C or with a retention time of about 31 min was identified as bis(2-ethylhexyl) phthalate. Larger quantities of the extracted compounds were obtained from the native range than from the crested wheatgrass soils. Fifty years was not long enough for organic matter of soil cultivated for only 5 years to regain its original quantitative chemical composition under the prevailing climatic conditions.

Crested wheatgrass (*Agropyron cristatum* Gaertn.) is a useful pasture grass for the revegetation of abandoned or marginal cropland, primarily because of increased yield compared to native range (Hull and Klomp 1966; Smoliak et al. 1967). In Western Canada, however, environmentalists are demanding an increasingly greater role in the decision-making processes affecting rangelands. They consider the breaking up of native range and the subsequent seeding of cultivated forage species such as crested wheatgrass to be destructive and irreversible. To counteract these sentiments, an understanding of the long-term effects of crested wheatgrass on soil characteristics is desirable.

About 50 years after seeding, soil under crested wheatgrass stands appeared to be evolving toward an equilibrium somewhat different from that under adjacent native range. Differences were noted in such factors as bulk density, water-stable aggregates, total organic C, extractable organic C, polysaccharides, and moisture retention (Dormaar et al. 1978). Soil organic matter is related to all of these characteristics. Other characteristics of soil organic matter, such as certain solvent-soluble constituents, are responsible for part of the cation exchange capacity of the soil (Schnitzer and Gupta 1965) or are suggested to influence aggregation (Griffiths and Burns 1972).

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The purpose of this study was to compare organic solvent-soluble constituents present in alkaline hydrolysates of soil organic matter developed under native range and adjacent stands of 40- to 49-year-old stands of crested wheatgrass.

Material and Methods

Four pairs of plots, three pairs consisting of abandoned cropland seeded to crested wheatgrass nearly 50 years ago and adjoining range of the Mixed Prairie type (Sites 1, 2, and 4) and one pair where the native range was also on abandoned cropland (Site 3), were selected for the study. These sampling sites were the same as those described in previous studies (Smoliak et al. 1967; Dormaar et al. 1978).

Five 500-g soil samples were collected on October 20, 1976, from the Ah horizon at the four corners and the center of each sampling site, air-dried, ground to pass a 1-mm screen, and mixed to give one composite sample per site.

From each of the eight composite samples, 100 g were extracted in a Soxhlet apparatus for 24 hr with a mixture of ethanol-benzene (1:1) to eliminate fats and waxes (Dormaar et al. 1978). A 40-g subsample of this extracted soil was then hydrolyzed in 1,500 ml of 4% NaOH for 4 hr at 90°C under nitrogen to prevent possible antoxidation reactions (Morita 1965), cooled, acidified with HCl, and fractions presumably containing either phenolic or carboxylic acids, obtained (Burchfield and Storrs 1962; Morita 1965). (The diethyl ether should be of "distilled in glass" grade thereby eliminating the preservative 2,6-di-*tert*-butyl-4-methylphenol.) Aliquots from these two extracts were injected onto a 1 m × 3.1 I.D. mm stainless steel column packed with 5% FFAP on 60–80 mesh GasChrom Q in a Hewlett Packard 5710A gas chromatograph (gc). Controls were run in which the solvents with no soil sample were put through the entire procedure and then gas chromatographed. As the sample emerged, the components were detected by a flame ionization detector and recorded on a Hewlett Packard 3373B integrator with chart speed of 0.64 cm/min. The operating conditions were: N_2-flow rate of 30 ml/min; column temperature program from 100 to 250°C at a rate of 4°C/min; injection port temperature, 200°C; and detector temperature, 300°C.

To deal with the more volatile compounds in the extracts, the samples were not methylated. Materials representing major peaks were eluted from the gc column, collected in capillary tubes, and analyzed by mass spectrometry (Dupont mass spectrometer, model 21-491) and infrared spectrophotometry (Perkin-Elmer infrared spectrophotometer, model 457). The column temperature program

was set at a rate of 2°C/min to allow capillary collection of material of peaks between 200 and 250°C. Mass and IR spectra were compared with those of standards of known structure. Known compounds were also co-chromatographed with the original mixtures.

Results

The attempt to separate the extracts into fractions containing either phenols or carboxylic acids was not very successful. The gas chromatographs of both fractions generally showed the same compounds. Since the graphs of Sites 1, 2, and 4 were almost identical, only those of 'carboxyl'-containing compounds of Site 2 and have been presented for comparison with those of Site 3.

Larger quantities of the extracted compounds were found in extracts from the soils covered with native range than from those covered with crested wheatgrass (Fig. 1, a & b vs. c & d). The quantities of the various compounds were generally greater in the extracts from Sites 1, 2, and 4 than from Site 3 (Fig. 1, a & c vs. b & d).
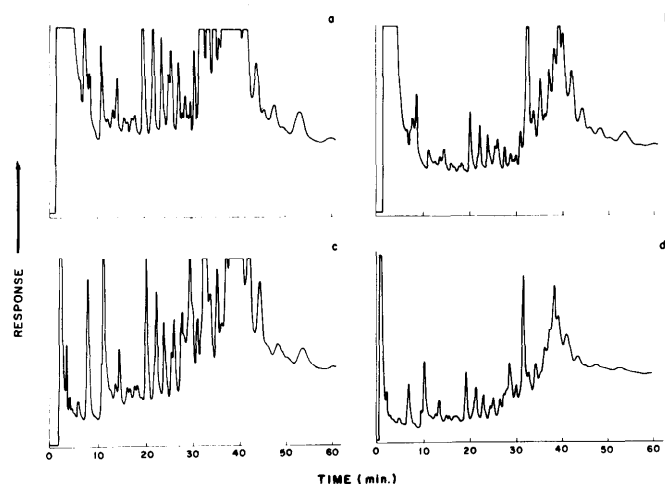

Fig. 1. *Gas chromatographic separation of 'carboxyl'-containing compounds in an alkaline extract of soils under (a) continuous native range (Site 2); (b) native range on eroded abandoned cropland (Site3); (c) crested wheatgrass on abandoned cropland (Site 2); and (d) crested wheatgrass on eroded abandoned cropland (Site 3).*

No major attempts were made to identify the multitude of peaks since we were only interested in patterns. Even so, the peak at 222°C (about 31 min retention time) was identified as bis(2-ethylhexyl) phtalate or dioctyl phthalate (Windholz et al. 1976; listed, incidentally, as two separate compounds in Schnitzer and Khan 1972, p. 181-182). The C content of this compound represented 0.86, 0.32, 0.46, and 0.10% of the total soil C of the native range Sites 2 and 3 and crested wheatgrass Sites 2 and 3, respectively. The C content of the material injected into the gc represented about 4,500, 1,300, 2,300, and 500 kg/ha to a depth of 15 cm respectively.

Discussion

Native range of Sites 1, 2, and 4 had never been broken while that of Site 3 had been cultivated for 5 years, then abandoned about 1928, and the native vegetation allowed to re-establish by secondary succession. By 1977, there was little visible evidence that the site had ever been cultivated. Nevertheless, through a comparison of soils data, it was possible to detect differences between native range of Sites 1, 2, and 4 and that of Site 3 (Fig. 1, a vs. b). Native range soil had greater recuperative power

following disturbance than crested wheatgrass soil (Fig. 1, b vs. d), particularly in the light of the comparison of crested wheatgrass vs. undisturbed native range soils (Fig. 1, c vs. a).

The difference between crested wheatgrass sown into abandoned cropland of Sites 1, 2, and 4 with that sown into eroded abandoned cropland of Site 3 (Fig. 1, c vs. d) seems somewhat anomalous. Not only was the recovery of the native range still not quantitative in terms of comparable organic solvent-soluble compounds, but also the soil under the crested wheatgrass of Site 3 showed the same phenomenon in relation to Sites 1, 2, and 4. However, the effect on the soil of the crested wheatgrass of Site 3 probably required longer to express since the plot area was situated within the larger abandoned field, itself slowly reverting to native range. This meant that the plot area was not as well protected from erosion forces as the other crested wheatgrass sites, particularly in the early 1930's on this somewhat exposed location.

Although a good root system is recognized as being essential to the utilization of soil moisture and the uptake of soil nutrients, the range manager is most interested in above-ground vegetation production because it provides forage for his animals and plant litter for ground cover. Crested wheatgrass outyielded native range by 1.08 to 12.42 times in the years for which data were available and produced, on the average, about twice as much forage (Dormaar et al. 1979). Nevertheless, the soil under crested wheatgrass stands had not returned to its original, or climax, condition under the semiarid climate of the study sites. Thus, environmentalists do have some reason for concern. Bulk densities tended to be higher under crested wheatgrass while energy flow was greater under the native range system (Dormaar et al. 1978). The latter seemed to explain the presence of organic matter that was more stable and less extractable and the increased aggregation of soil particles on the native range sites compared with the crested wheatgrass sites. In practical terms, if plans are to renovate land that has been under crested wheatgrass for many years, the range manager would be well advised to exercise caution as such soils are more susceptible to erosion than the native range soils.

Time, the essential parameter of any changing system, is seldom mentioned (Burges 1960). In the study area, it will take at least 50 years to restore the chemical characteristics of an eroded Ah horizon to the dynamic equilibrium that existed before disturbance.

Although the average C contents were only 1.15% for native range soils and 1.08% for crested wheatgrass soils (Dormaar et al. 1978), the organic function of soils of the semiarid regions of the world is known to exert an influence on soil transformations far exceeding its proportion by weight (Wildung et al. 1971). The present study can only be considered a first step toward the elucidation of organic compounds in semiarid soils. Fuller (1974) observed from the literature that the relatively low humus content of semiarid soils is due chiefly to the activity of a highly biogenic soil process, and not, as previously supposed, to a low amount of vegetative remains entering the soil. The role of individual compounds within the soil system may become quite significant under these conditions.

We do not know how widely bis(2-ethylhexyl)phthalate, the compound identified in this study, occurs. It is a hydrophobic compound and has been isolated in small amounts from fulvic acids of other soils (Schnitzer and Khan 1972). Fulvic acid is a water-soluble humic material with relatively low molecular weight that occurs widely in soils and waters. Ogner and Schnitzer (1970) showed that it can combine with lyophobic

organic compounds to form stable 'complexes', which are soluble in water. The significance of the presence of such complexes in range soils is difficult to assess. Information regarding the mechanisms and extent of the participation of the soil organic fraction and the soil microflora in terms of exchange capacity, nutrient supply, heat sinks, energy supply, and effect on plant physiological processes is far from complete for semiarid climates (Wildung et al. 1971). In a comprehensive summary of the soil of the drier regions (Dregne 1976), little is said about soil organic matter *per se* or about its quality. Thus, to make the best use of lands in semiarid regions, better understanding of the biochemical processes that occur in such soils would be desirable.

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