MONTANA STATE UNIVERSITY

# The effect of controlled water level and nitrogen fertilization on some physical and chemical characteristics of mountain meadow soils

by Harold A R Houlton

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Soils
Montana State University
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Abstract:
Mountain meadow soil from the Big Hole Valley of Montana was put into 55-gallon oil drums in a manner so as not to disturb the natural sequence of horizons. The soil was transported to the Experiment Station at Bozeman, Montana, where controlled water level and nitrogen fertilizer studies were conducted for a period of three years. At the end of this time, physical and chemical determinations were made in an effort to ascertain what changes, if any, in the physical and chemical characteristics of the 0- to 3-inch and 3- to 6-inch depths had occurred.

The experimental data shows that water treatment was the most important in influencing characteristics of this soil. High water levels increased capillary pore space and maintained a high organic matter content.

Nitrogen fertilization was found to be effective in increasing nitrifiable nitrogen, helping to maintain organic matter content, and also increasing capillary pore space.

# THE EFFECT OF CONTROLLED WATER LEVEL AND NITROGEN FERTILIZATION ON SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF MOUNTAIN MEADOW SOILS

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## ABSTRACT

Mountain meadow soil from the Big Hole Valley of Montana was put into 55-gallon oil drums in a manner so as not to disturb the natural sequence of horizons. The soil was transported to the Experiment Station at Bozeman, Montana, where controlled water level and nitrogen fertilizer studies were conducted for a period of three years. At the end of this time, physical and chemical determinations were made in an effort to ascertain what changes, if any, in the physical and chemical characteristics of the 0- to 3-inch and 3- to 6-inch depths had occurred.

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# INTRODUCTION

The soil used for this study was taken from the Big Hole River Valley of southwestern Montana. The valley is located in mountain terrain at altitudes in excess of 5,000 feet. The average temperature for the months from May to August, inclusive, is 55° F. The growing season is 100 days or less. Ranching and hay raising constitute the major portion of the agriculture in the valley.

The mountain meadow soils of the valley are characterized by a heavy mat of undecomposed organic material. This mat presents a cultivation problem. No ordinary plow or cultivator is effective in breaking up this mat; therefore, a seedbed is difficult to establish.

These soils are subjected to extreme fluctuations of water table level. The water conditions range from flood conditions in the spring and early summer to dry conditions in late summer. The irrigation method now in use is of the "wild flood type". Water is turned onto the land and is pretty much allowed to find its own way. Very little attempt is made to control it. This situation accentuates the high water table condition. The resulting vegetation has a high proportion of sedges and other water-loving species.

In 1954, plans were initiated to conduct studies on these soils. The objectives of these studies were to determine the

1. Influence of different water table levels on soil properties and the release of plant nutrients.
2. Influence and relative effectiveness of fertilizers and soil amendments.

3. Influence and effectiveness of certain tillage practices.

This phase of the study is concerned with the effects of water levels and nitrogen fertilization on the physical and chemical properties of these soils.

## REVIEW OF LITERATURE

There is evidence, as indicated by Bertrand and Kohnke (4), that bulk density, pore size distribution, and moisture content effect plant root growth through their influence on oxygen diffusion.

Epstein and Kohnke (8) found that high moisture content and compaction of the soil decreased the oxygen at the 8-inch depth. They also determined that, when organic matter was added to the soil, a lowering of the oxygen content resulted.

With high water conditions which prevent adequate supplies of oxygen, anaerobic conditions predominate, with the formation of large amounts of reduced soil constituents. Some of the changes in state of oxidation of certain soil constituents are given by Bradford (5) as follows:

| Element | Normal form in well-oxidized soils | Reduced form in water-logged soils |
|---|---|---|
| Carbon | $CO_2$ | $CH_4$ |
| Carbon | --- | Complex aldehydes, etc. |
| Nitrogen | $NO_3^-$ | $N_2$ and $NH_3$ |
| Sulfur | $SO_4^{--}$ | $H_2S$ |
| Iron | $Fe^{+++}$ (ferric) | $Fe^{++}$ (ferrous) |
| Manganese | $Mn^{+++}$ (manganic) | $Mn^{++}$ (manganous) |

Lawton (10) reported an increase in the extractable ferrous iron content with an associated decrease in extractable ferric iron when soils were maintained at high moisture content.

Anaerobic conditions resulting from waterlogging of soil may cause an increase (very large in some soils) in exchangeable divalent manganese, as reported by Leeper (12).

Benidict (3) reported that anaerobic decomposition of organic matter in waterlogged soils produces substances which are toxic to plants.

Wet, poorly drained soils are favorable to the development of anaerobes and inhibitive to aerobes. Since anaerobes are capable of using oxygen that is in chemical combination with soil components to meet the needs of their life processes, their activities effect reduction of nitrates.

Willis and Sturgis (23) observed that large quantities of nitrogen as ammonia are lost from waterlogged soils.

De and Sarker (6) found that much of the difference in nitrogen between the amount of nitrate applied to a waterlogged soil and that recoverable as ammonia was due to nitrogen assimilated by the increased population of micro-organisms.

Wallihan (22) found that there was a relatively rapid rate of nitrate production following the drainage of waterlogged soils.

Stephens (18) found that on Florida peat and muck soils as the water table was lowered the organic matter decomposition increased.

Baver (1) states that wet soils are cold soils and thus microbial activity is depressed. Nutrient availability dependent on this activity will be correspondingly depressed.

The consideration of varying water levels with nitrogen fertilization would seem to be involved directly with several soil-water-soil atmosphere relationships. High water levels exclude the normal soil atmosphere required for micro-organisms to function aerobically. The anaerobic conditions directly affect the amount of organic matter being activated. Organic matter in its different forms and degrees of oxidation would influence the non-capillary pore space through its granulating action. Capillary pore space would also be conditioned by the colloids produced from organic matter.

The release of important plant nutrients such as nitrogen and phosphorus from organic matter decomposition would be influenced by the organic matter decomposition.

Again, with reference to organic matter colloids, the total exchange capacity would be conditioned according to the amount and kind of colloid produced under different water conditions.

The above statements are accepted and professed in soils texts (1), (13), (15), (16), (19) but with little or no supporting quantitative data.

# MATERIALS AND METHODS

## Description and Method of Filling Soil Tanks

As this project was initiated before the author's time at Montana State College, the collection of the drums of mountain meadow soil and the resulting experimental setup were under the supervision of Dr. J. A. Asleson. The method of filling the soil tanks, as they were popularly called, shall be directly quoted from Dr. Asleson's first report[1].

> "Twenty-four 55-gallon drums were filled with undisturbed sod and soil from a meadow in the Big Hole River Valley of southwestern Montana. The soil was placed in the barrels in such a way that the sequence of horizons approximated the profile in the field. The surface 10 inches of the profile, including the sod, were cut out as to size and shape so as to be placed in the barrels as nearly undisturbed as possible. An attempt was made to keep the composition and density of the forage in all barrels as uniform as possible. The barrels, previously fitted with outlets, were transported to Bozeman. Each barrel was fitted with a 3/4-inch pipe drain and stand pipe. They were then placed in a deep pit and soil filled in around the barrels. The water level within the barrels will be controlled by means of stand pipes." (See figure 1).

The soil profile for the soil tanks is described briefly as follows:

0 to 3 inches - undecomposed organic matter

3 to 10 inches - black silt loam

10 to 17 inches - black coarse sandy loam

17 to 36 inches - light-brown coarse sand

36 inches + - gravel

To prevent corrosive action on the walls of the barrels, a coat of water-resistant asphalt paint was applied to the inside walls before soil

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[1]Asleson, J. A. Annual report, Dept. of Agronomy and Soils, Montana State College, 1954.

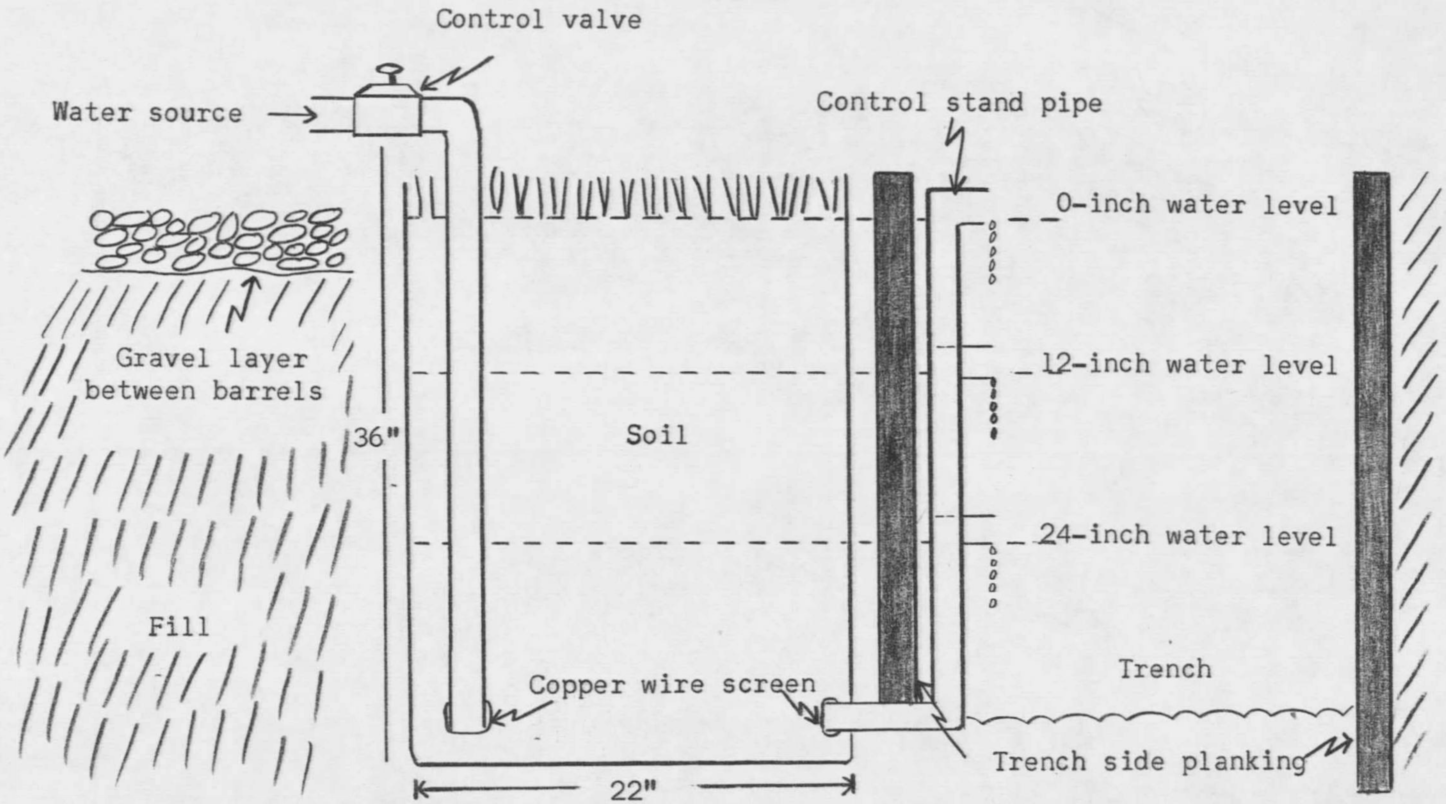


Figure 1. Cut-away view of soil tank with control stand pipe showing for the three water levels.