Effect of livestock grazing on soil micro-organisms of cracking and self mulching vertisol

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Abstract

The impact of grazing on physical properties of Vertisol was studied from 1996 to 2000 in the Ethiopian highlands. The study was conducted at two sites with 0-4 % and 4-8 % slopes at Tero Jemjem watershed in Ginchi, 80 km west of Addis Ababa. The main objective of this work was to study effect of livestock on soil microorganisms of the cracking and self-mulching Vertisol. The stocking rate was moderate grazing 1.8 animal-unit months per hectare (AUM) ha^{-1}, heavy grazing 3.0 animal-unit months per hectare (AUM) ha^{-1} (3.0 AUM) ha^{-1} and a control treatment with no grazing. Soil bacterial content was high in medium grazed treatments at 0-4% slope in alls sampling seasons. In contrast the soil fungal content was high in non-grazed plots. Soil nitrifying bacteria was high in clipping treatments as compared to the rest of the treatments. The soil fungal quantity differed significantly with sampling seasons; highly significant correlation coefficient was observed between soil fungal quantities and sampling seasons. There was also highly significant correlation between soil fungal and soil bacteria quantity.

Keywords: Cracking and self-mulching Vertisol, Functional groups, Entrobacteriaceae, Nitrifying and denitrifying bacteria, , Phosphorous solublizing microorganisms, Soil bacteria, Soil fungi

Introduction

Vertisols occupy about 105 million ha in Africa and about 12.6 million ha in Ethiopia. Previously Vertisols were regarded as primarily suited for pasture. However, due to drastic population increases and high demand for cereal crops they have turned into cereal cropping land.

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Changes in the physical properties of cracking Vertisols occur with changes in water content because of swelling and shrinking (Bridge and Ross 1984; Coughlan 1984; Grismer 1992; Girma 1998; Girma *et al.*, 2002). During the heavy rainy season when Vertisols are under waterlogged condition, grazing is often shifted from gentle slopes, to steeper slopes.

The effect of grazing is not simply the removal of herbage from grass plants (Manske, 1998**)**, grazing also changes physiological processes in all parts of the plants; alters the plant community microclimate; the climatic conditions around parts of a plant or within a small area of a plant community by changing light transmission, moisture relations and temperature; and changes the soil environment, thereby affecting soil organism activity.

Low water availability can inhibit microbial activity by lowering intracellular water potential and thus reducing hydration and activity of enzymes. In solid matrices, low water content may also reduce microbial activity by restricting substrate supply. For the soil-microbial system the substrate limitation was the major inhibiting factor when soil water potentials were greater than -0.6 MPa, whereas adverse physiological effects associated with cell dehydration were more inhibiting at water potentials of less than -0.6 MPa (Stark and Firestone, 1995).

The inherent physical properties of Vertisol could be improved through better livestock grazing and crop production. Thus it is important to study the soil microorganism activities of the grazing land. Though the primary role of fungi and some soil bacteria is to break down organic matter, other bacteria help make nitrogen available to plant roots. When moisture and temperatures are suitable, bacteria convert the ammonium nitrogen into nitrate nitrogen, the form of nitrogen that most plants use (NGA, 2006).

Bacteria in soils live in a film of water around plant roots or other particles, and their activity is dependent on the temperature and the amount of available moisture. In general, bacteria concentrations in surface water is 10^6 cells/ml, and 10^9 cells/ml in soils and sediments.

Fungi secrete enzymes that can break down cellulose into glucose. Fungi are the only known organisms that degrade lignin completely. Cellulose and lignin are structural materials in plants that are difficult to degrade. The fungi do not use the breakdown products of lignin, but instead they use hydrogen peroxide to oxidize lignin in place. The breakdown products diffuse away, exposing the cellulose to enzymatic attack. As climate changes occur, bacterial populations in the soil could be significantly impacted. As temperature increases, bacterial numbers could increase, resulting in greater immobilization of nutrients in their biomass, causing greater nitrogen limitation of plant growth (Colman 1985; Colman *et al.*, 1992).

In all grassland and most agricultural soils have ratios of total fungal to total bacterial biomass is less than one (F/B < 1). In the most productive agricultural systems, however, the ratio of total fungal to total bacterial biomass equals one (F/B = 1) or the biomass of fungi and bacteria is even. When agricultural soils become fungal-dominated, productivity will be reduced, and in most cases, liming and mixing of the soil (plowing) is needed to return the system to a bacterial-dominated soil. Bacteria also represent an important supply of inorganic and organic nutrients under nutrient limiting conditions (Jurgens, 2000; http://www.rain.org/~sals/ingham.html).

Decomposition releases the mineral nutrients (e.g., N, P, K) bound up in dead organic matter in an inorganic form that is available for primary producers to use. Without this recycling of inorganic nutrients, primary productivity on the globe would stop. On land, most of the decomposition (also called "mineralization") of dead organic matter occurs at the soil surface, and the rate of decomposition is a function of moisture and temperature or too little or too much of either reduces the rate of decomposition.

Fungi are the most important decomposers of structural plant compounds; cellulose and lignin – but lignin is not broken down when oxygen is absent. The only organisms capable of removing N_2 gas from the atmosphere and "fixing" it into a useable nitrogen form (NH_3) are bacteria.

Oriana *et al.*, (2005) reported that the distribution of 207 taxa of fungi revealed that the elevation was the main factor of fungal variability; the effect of grazing and slope position was associated with less variability. Biologically effective grazing management can stimulate activity of a second type of beneficial soil fungi. These fungi improve soil structure. Ectomycorrhizal fungi previously unknown in the mixed grass prairie were recently found in association with roots of grass plants managed with the twice-over rotation grazing system, which coordinates grazing periods with grass growth stages when defoliation resistance mechanisms are stimulated.

Materials and methods

Study description

The study was conducted from 1996-2000 at Tero Jemjem watershed (2190-2440 m a. s. l.) in Ginchi, 80 km west of Addis Ababa, Ethiopia (38° 13′ 9″ E and 9° 1 ′ 5″ N). The annual rainfall is 1150 mm and the rainy season starts in June, peaks in August and tails off in September. The mean annual temperature is about 17 °C with insignificant seasonal variation, however, the period from October to March is slightly warmer and June to September is cooler.

The soils at the experimental site belong to Eutric Vertisols, with very high clay content (55-78% clay). Due to high smecitite clay content, these soils have marked swelling-and –shrinking properties (Kamara and Haque 1988). The treatments were no grazing (NOG, control), where animal grazing was excluded using 10 m by 10 m fenced enclosure, moderate grazing (MDG, 1.8 animal unit month per hectare) and heavy grazing (HVG, 3.0 animal unit month per hectare). The grazing pressure at MDG was regulated by opening flexible fencing around the plots for 3 days a week to allow free access for farmers' animals. There was no fencing around plots subjected to heavy grazing (HVG). The NOG plots were fenced and kept closed to livestock grazing through out the experiment. The number and type of animals and duration of grazing in the MDG and HVG treatments were recorded daily to determine the stocking rate and grazing intensity. Similar cultural practices as used by surrounding farmers were imposed; manure was collected from grazed plots by the herders and used as source of fuel. Stocking density was expressed as animal units per hectare (AU/ha) and calculated as proposed by Scarnecchi (1985). An animal unit (AU) is defined as a 450 kg steer at 30 months of age (Edwards 1981; Le Hou′erou 1989). The grazing animals were local zebu cattle, donkeys and horses, sheep and goats that belonged to the farmers in the watershed.

Statistical Analysis

Statistical Analysis was done using General Linear model of SPSS. 11

Results and discussion

Soil bacteria and fungi

Changes in light transmission, moisture relations and temperature; and changes in the soil environment affect soil organism activity **(**Manske, 1998). Provided that the dry wet soil condition affects the microorganisms in cracking and self-mulching Vertisol. Thus the dry-cool, dry-wet and wet sampling period was set for soil microorganisms investigation. The result showed that the soil bacterial quantity in medium grazed treatment at 0-4 % slope was higher than the rest of the treatments in all sampling seasons (Table 1a). On the other hand in dry-cool season the soil bacterial content was high in medium grazed plots at 4-8% slope. In contrast in dry-wet and wet season soil bacterial content was high at 4-8% compared to 0-4% slope. In general, bacterial concentrations in surface water is 10^6 cells/ml, and 10^9 cells/ml in soils and sediments (Colman *et al*., 1992).

Fungi secrete enzymes that can break down cellulose into glucose. Cellulose and lignin are structural materials in plants that are difficult to degrade (Colman *et al*., 1985). Often the soil fungi are active where grass covers is abundant under suitable moisture and soil temperature conditions. Apparently, the soil fungal quantity was the highest in non-grazed plots in all sampling seasons in both slope categories (Table 1b). Similar trend in soil fungal quantities was measured at 4-8% slope. The favorable season for fungal activity was wet season in all treatments, and decomposition releases the mineral nutrients (e.g., N, P, and K) bound up in dead organic matter in an inorganic form that is available for primary producers to use by microorganisms(Llewellyn, 2004). Biologically effective grazing management can stimulate activity of a second type of beneficial soil fungi (Ectomycorrhiza). These fungi improve soil structure (Oriana *et al*., 2005). Girma *et al*., (2002) reported water infiltration was low in heavily grazed plots and compaction was high on the same plots.

Functional groups

The only organisms capable of removing N_2 gas from the atmosphere and "**fixing**" it into a useable nitrogen form (NH_3) are bacteria. Grass clipping from grazed plants changes the botanical composition and improves annual legumes to dominate, which can easily produce root nodules for nitrogen fixing bacterial development. As a result, the soil nitrifying bacteria was high in clipping treatment than the rest of the treatments particularly, in dry-wet and wet seasons (Table 2). When moisture and temperatures are suitable, bacteria convert the ammonium nitrogen into nitrate nitrogen, the form of nitrogen that most plants use (NGA, 2006). The nitrifying bacteria were a bit higher at 4-8% slope as compared to the 0-4% slope. Similar trend was measured in heavily grazed plots for nitrifying bacteria. According to Jurgens's (2000) report all grassland and most agricultural soils have ratios of total fungal to total bacterial biomass less than one (F/B < 1). Low water availability can inhibit microbial activity by lowering intracellular water potential and thus reducing hydration and activity of enzymes (Stark and Firestone, 1995). In such condition denitrifying bacteria could release Nitrous oxide to the air, which is a loss of nitrogen. The quantity of nitrifying bacteria in non-grazed and medium grazed treatments showed similar trends. However, the denitrifying bacteria in heavily grazed treatments were a bit high as compared to the rest of the treatments (Table 2). The Entrobacteriaceae content was high in heavily grazed plots in dry-cool and wet seasons at both slope categories. There were no significant differences in phosphorous solublizing microorganisms in all sampling seasons and at both slope categories.

Table 1a. Effect of grazing pressure on bacterial population (bacteria/ g of soil)

Treatment	Season - 0-4 % Slope					
	Dry-cool		Dry-wet		Wet	
	Mean	sd	Mean	sd	Mean	sd
NOG	5.9E+06	4.6E+06	9.2E+05	4.3E+05	7.1E+06	3.9E+06
MDG	9.7E+06	4.4E+06	1.4E+06	9.3E+05	8.8E+06	3.4E+06
HVG	5.1E+06	2.6E+06	6.5E+05	4.8E+05	7.6E+06	2.3E+06
Treatment	**Season - 4-8 % Slope**					
	Dry-cool		**Dry -wet**		**Wet**	
	Mean	**sd**	**Mean**	**sd**	**Mean**	**sd**
NOG	2.3E+06	9.2E+05	2.7E+06	3.3E+06	1.1E+07	1.0E+07
MDG	1.1E+07	9.0E+06	1.3E+06	2.6E+05	4.5E+06	2.6E+06
HVG	2.8E+06	1.5E+06	1.4E+06	9.2E+05	6.0E+06	4.6E+06

Table 1b. Effect of grazing pressure fungal population (fungi/ g of soil).

Treatment	Season - 0-4 % Slope					
	Dry-cool		Dry-wet		Wet	
	Mean	sd	Mean	sd	Mean	sd
NOG	9.0E+04	7.9E+04	1.8E+04	6.3E+03	2.6E+05	1.6E+05
MDG	4.2E+04	1.8E+04	5.5E+03	6.1E+03	2.5E+05	1.5E+05
HVG	7.5E+04	2.2E+04	6.7E+03	1.4E+03	1.4E+05	8.4E+04
Treatment	**Season - 4-8 % Slope**					
	Dry-cool		**Dry-wet**		**Wet**	
	Mean	**sd**	**Mean**	**sd**	**Mean**	**sd**
NOG	6.5E+04	7.5E+04	1.1E+04	5.0E+03	4.4E+05	3.6E+05
MDG	5.3E+04	5.9E+04	9.8E+03	8.8E+03	7.8E+04	1.9E+04
HVG	2.3E+04	2.8E+04	7.3E+03	3.8E+03	3.8E+04	2.2E+04

Table 2. Average percentage of functional groups as influenced by grazing pressure

Treatment	Functional group	Season - Slope (0-4%)			Season Slope (4-8%)		
		Dry-cool	Dry-wet	Wet	Dry-cool	Dry-wet	Wet
NOG	nitrifying	5.5	0.001	4.5	4.8	0.002	5.2
	de-nitrifying	0.01	2	0.02	0.01	2	0.03
	entrobacteriaceae	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	psm	0.15	0.005	0.16	0.14	0.001	0.16
MDG	nitrifying	4.8	0.001	5	5	0.001	5
	de-nitrifying	0.001	1.5	0.001	0.001	1.2	0.001
	entrobacteriaceae	0.05	0.001	0.05	0.045	0.001	0.055
	psm	0.04	0.001	0.055	0.05	0.001	0.06
CLIPP	nitrifying	6.6	0.01	6	7	0.03	8
	de-nitrifying	0.05	2	0.05	0.05	1.85	0.05
	entrobacteriaceae	0.05	0.005	0.055	0.03	0.006	0.05
	psm	0.03	0.001	0.02	0.03	0.001	0.02
HVG	nitrifying	6.5	0.05	7	7	0.08	6
	de-nitrifying	0.001	3	0.005	0.002	3	0.005
	entrobacteriaceae	2.5	0.01	2.5	2.5	0.005	3.5
	psm	0.05	0.001	0.1	0.3	<0.001	0.2

psm = phosphate solublizing microorganizms

The data in Table 3 showed that soil fungal quantity was statistically significant with sampling seasons. The correlation coefficient between season and soil fungal quantity was highly significant, and the correlation coefficient between soil fungal quantity in and soil bacterial quantity was highly significant (Table 4).

Table 3. General linear model test on different parameters on microbial population

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	*Sig.
Corrected Model	Bacteria/g of soil	1.11E+14	6	1.84E+13	0.8	0.574
	Fungi/g of soil	2.90E+11	6	48261893102	3.14	0.01
Intercept	Bacteria/g of soil	3.52E+13	1	3.52E+13	1.53	0.222
	Fungi/g of soil	1437097.476	1	1437097.476	0	0.992
Season	Bacteria/g of soil	1.88E+13	1	1.88E+13	0.81	0.371
	Fungi/g of soil	1.77E+11	1	1.77E+11	11.5	0.001
Site	Bacteria/g of soil	2.68E+12	1	2.68E+12	0.12	0.735
	Fungi/g of soil	4732041667	1	4732041667	0.31	0.582
Treatment	Bacteria/g of soil	9.02E+13	3	3.01E+13	1.31	0.283
	Fungi/g of soil	1.06E+11	3	35398502347	2.3	0.088
Error	Bacteria/g of soil	1.22E+15	53	2.30E+13		
	Fungi/g of soil	8.15E+11	53	15386255734		
Total	Bacteria/g of soil	2.66E+15	60			
	Fungi/g of soil	1.55E+12	60			
Corrected Total	Bacteria/g of soil	1.33E+15	59			
	Fungi/g of soil	1.11E+12	59			

*Sig. < 0.05

Table 9. Correlation between different parameters on microbial population as influnced by grazing pressure in Vertisol.

	Season	**Slope**	**Treatment**	**Bacteria/g of soil**	**Fungi/g of soil**
Season	1	0	0	0.093	.338**
Slope	0	1	-0.055	-0.052	-0.155
Treatment	0	-0.055	1	-0.064	-0.219
Bacteria/g of soil	0.093	-0.052	-0.064	1	.601**
Fungi/g of soil	.338**	-0.155	-0.219	.601**	1

Conclusions

Soil bacterial content was high in medium grazed treatments at 0-4% slope in alls sampling seasons. In contrast the Soil fungal content was high in non-grazed plots. Soil nitrifying bacteria was high in clipping treatments as compared to the rest of the treatments. The denitrifying bacteria and entrobacteriaceae are dominant in heavy grazing pressure. There were no significant differences in phosphorous solublizing microorganism content among the treatments. The soil fungal quantity differed significantly with sampling seasons; highly significant correlation coefficient was recorded between soil fungal quantities and sampling seasons. There is also highly significant correlation between soil fungal and soil bacteria quantity.

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