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Short-term green manure and tillage management effects on maize yield and soil quality in an Andisol

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Abstract

Andisols are very important land resources supporting high human population density. Maize (*Zea mays* L.) production on Andisols located in the Purhepecha Region of central Mexico is representative of the highlands conditions of Mexico and Latin America. Farmers struggle with low crop yield and low soil nutrient availability. A 2-year field study was conducted to evaluate the effects of green manures either tilled into the soil (CT) or cut and left on the surface as a mulch (ZT), on maize yield and soil quality. Green manure treatments were: vetch (*Vicia sativa* L.), oat (*Avena sativa* L.) and none. No extra N was added to maize. Green manure and tillage had a significant effect on maize grain yield, N uptake and P uptake with CT vetch performing better than ZT oat. Soil organic C and total N were significantly higher under ZT than under CT management. Soils with vetch had higher P concentration. Soil under ZT oat had the highest infiltration rate and penetration resistance compared with other treatments. There appears to be a trade off between soil productivity and intrinsic soil physical properties among soil treatments.

Keywords: Andisol; Green manure; Soil indicators; Soil quality; Tillage

1. Introduction

Andisols occur in populated and important agricultural areas all over the world (Shoji et al., 1993). These soils are characterized by high amount of organic matter; very low rate of N and P mineralization; high P adsorption levels and fragile physical properties when converted to agriculture and mechanical tillage. Agricultural practices such as CT and inappropriate fertilization are causing gradual deterioration of Andisols in the Purhepecha Region of the

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Mexican highlands (Santos-Ladín, 1986). In this region, 2.4–3.0 Mg ha^{-1} of conventionally tilled soils are lost every year due to erosion (Tiscareño et al., 1999) with depletion of macronutrients, from the agricultural fields. Farmers need to add increasing amounts of N as chemical fertilizer to maintain maize yields (Astier et al., 2000).

Green manuring is the process of turning a crop into the soil, whether originally intended or not, irrespective of its state of maturity, for the purpose of affecting some agronomic improvement (Mac Rae and Mehuys, 1985). Green manures are known to increase soil N and P availability for the following crop and at the same time, contribute to the conservation of soil organic matter and soil biological, physical and chemical properties (Mac Rae and Mehuys, 1985; Mc Vay et al., 1989).

Acton and Gregorich (1995) defined soil quality as the condition of a soil to maintain plant growth without soil degradation or environmental damage. Soil quality evaluation frameworks must be sensitive to the specific time and spatial scale of the study (Astier et al., 2002).

The objective of this study was to evaluate transitional effects over 2 years on soil productivity and soil quality resulting from green manure species and tillage management. For that purpose, the best (most sensitive) indicators were selected.

2. Materials and methods

2.1. Experimental site and design

An experiment was conducted at Casas Blancas, Michoacán (19°25′N, 101°36′E, altitude of 2298 m) in the Lake Zirahuén Watershed within the Purepecha Region of Mexico from 1996 to 1998. The region is sub-humid with rains from May to October. Average annual rainfall is 1100 mm and annual temperature is 14 °C with early frost events and hail storms. The soil is an Andisol Humic and Ocric (Table 1). The field was under natural vegetation (mainly grasses) and without plowing for more than 6 years before the experiment was established. The design was a complete randomized block with five replicates of each treatment. Each plot measured 15 m × 15 m.

Table 1
Soil characteristics in Casas Blancas, Michoacán, Mexico

Characteristics	0–10 cm	10–20 cm
Texture (%)		
Sand	46.3	51.3
Silt	35.0	31.2
Clay	18.8	17.5
Bulk density (g cm^{-3})	0.63	0.60
P retention (%)	98	
PH–H_2O (1:2:5)	6	6
Organic matter (%)	9.4	8.9
Organic carbon (mg C g^{-1} soil)	54.5	51.5
Total nitrogen (mg N g^{-1} soil)	3.8	3.6
Available phosphorous		
P Bray (μg P g^{-1} soil)	1.3	0.9
P Olsen (μg P g^{-1} soil)	8	
Exchangeable cations (μg g^{-1})		
Ca^{++}	1396	1595
Mg^{++}	111	129
K^{+}	285	248
Na^{+}	2.0	4.5

2.2. Green manure and crop management

The experiment consisted of a green manure-maize rotation from July of 1996 until the end of the growing season of 1998. Tillage management treatments and green manure species were: (1) conventional tillage with no green manure or fertilization (CCT); (2) conventional tillage with vetch (VsCT); (3) zero tillage with vetch (VsZT); (4) conventional tillage with oat (AsCT) and zero tillage with oat (AsZT). The green manure and maize establishment sequence was the following: green manure in July 1996 and maize in April 1997; green manure in November 1997 and maize in April 1998. Plots with vetch and oat were established at a seed rate of 100 and 200 kg ha^{-1}, respectively. At 20% flowering time, these green manures were either tilled into the soil with a hand-hoe in the manner of a chisel plough (CT), or cut and left on the surface as a mulch (ZT). Phosphorous fertilizer was added to the vetch and oat with the purpose of increasing biomass accumulation of both green manures and maximizing biological N fixation of the vetch (Flach et al., 1987; De León and Etchevers-Barra, 1999). Triple super phosphate (TSP, 46% P_2O_5) was broadcasted at 100 kg ha^{-1} at seeding time and incorporated into the soil with a hand-hoe in both CT and ZT. To prevent contamination, a buffer zone 3 m