Soil Organic Amendments Change Low Organic Matter Agroecosystems

Milton E. McGiffen, Jr.
Dept of Botany and Plant Science
University of California
Riverside, California
USA

Inmaculada Lebron
U.S. Salinity Lab,
450 W Big Springs Road, Riverside
California
USA

Mathieu Ngouajio
Dept of Horticulture,
Michigan State University,
East Lansing
Michigan
USA

C.M. Hutchinson
University of Florida/IFAS,
Hastings Research and Education Center, Hastings,
Florida
USA

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Abstract

A field site in the Coachella Valley of California was selected as an ideal experimental location to study the effect of organic amendments on soil ecology and crop productivity. The high temperatures, low rainfall, and frequent irrigation of low desert agriculture leads to rapid breakdown of organic residue and soils naturally low in organic matter. Because organic carbon is relatively scarce in desert soils, amending with compost or cover crops may have a more dramatic and easily detectable effect than in temperate regions. Our experimental treatments included all possible combinations of summer cover crops and vegetable crop management systems. Summer cover crops were dry fallow or sudangrass or cowpea. Fall lettuce was followed by spring cantaloupe. Both crops were continuously managed as either conventional, organic, or an integrated system that reduced insecticide applications. The experimental design allowed direct comparisons of many combinations of organic or conventional fertility and pest management regimes. Yields in the first year of study were lower in the organic plots. However, yields for the following year for conventional and organic systems were equal despite less effective insect control in the organic system. Soil organic matter content was correlated with soil structure and lettuce yield. However, the range of organic carbon was very narrow (0.5-1%) and it was correlated with the clay percentage of the soils. The negative charges of the surface of the clays act as an absorbent interface where the organic molecules attach. Attachment to the clay surfaces protected organic matter from microbial degradation so that it could accumulate in the soil, but the amount of organic carbon accumulated was restricted to the limited amount of colloidal or clay particles present in these sandy desert soils. Soil microbial respiration was related to the amount of organic carbon added as either cover crop or compost, indicating that microbes were degrading and using the organic residues as an energy source.

INTRODUCTION

Our research quantifies what is often called "the organic effect", i.e. the positive changes that result from the transition from conventional to organic production practices. Farmers often experience lower yields in the first few years of this transition, with a subsequent improvement of crop yields following several years of organic farming. This is often referred to as the organic transition effect or more simply the organic effect. Such increases in crop productivity are usually attributed to improvements in soil quality resulting from cover crops, organic amendments, and other aspects of organic crop production. Few studies have quantified the mechanisms that control the longer-term changes in yield that follow organic amendment. Our experimental design allowed comparison of both conventional and organic (e.g. no synthetic pesticide) management practices. We selected a desert soil with less than 0.5% organic matter content to allow greater discrimination between the effects of organic amendments versus effects that resulted from organic carbon already present in the soil before the experiments were initiated.

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MATERIALS AND METHODS

Field trials were conducted in 1999 and 2000 at the University of California Coachella Valley Agricultural Research Station in Thermal, CA. Cover crops were grown in the summer (from July to September) followed by lettuce ‘Shining Star’ in the fall (from October to December) and cantaloupe (*Cucumis melo* L.) in the spring (from February to June). The experiment was a factorial arranged in a split-plot design with four replications. The main-plot factor was summer cover crop type and the subplot factor was management system. Cover crop treatments included (i) summer cowpea (*Vigna unguiculata*) incorporated into the soil in the fall, (ii) summer cowpea used as surface mulch in the fall, (iii) summer sudangrass (*Sorghum vulgare*) incorporated into the soil in the fall, and (iv) summer dry fallow. Management practices included the organic, the integrated, and the conventional systems. The main-plot treatments were subdivided into three subplots of equal size each with six beds. The three subplots were then managed as conventional, organic, or integrated systems. The conventional and integrated management systems received synthetic fertilizers, and the organic treatments received compost. For insect control, a formulation of *Bacillus thuringiensis* subsp. aizawai (XenTari) was used in the organic plots, and bifenthrin (Capture) was used in the conventional and integrated management plots. In the organic and integrated management plots, insecticide applications were initiated only when a threshold of two cabbage loopers per ten plants was reached. In the conventional system however, there was a pre-established schedule of four applications. All treatments were kept in the same plots throughout the duration of the study.

Soil was sampled from the plots in January following the lettuce harvest, and microbial respiration was quantified as an indicator of microbial population activity. (Table 1). The soil was dried at room temperature, and bulk density (BD) was measured The soil core was then impregnated with an epoxy to prepare a thin section. Disturbed samples, collected at the same location as the undisturbed soil cores, were used to analyze the chemical composition of the saturation extract, the total soil organic carbon, and soil texture (Table 2).

RESULTS AND DISCUSSION

Incorporating the cowpea cover crop increased lettuce yields in Years 1 and 2 in both the conventional and organic systems (Figure 1). However, regardless of whether organic matter was added to the soil as compost or cowpea residue, there was an increase in yield and a decline in weed populations as soil organic matter increased from Year 1 through Year 2 (Figure 2). In Year 1, organic melons and lettuce had lower yields than the conventionally managed system. However, organic yield became equal to the conventional management system in Year 2.

Conventionally-managed summer fallow had no added organic matter and had the lowest microbial population (Table 1). Organically-managed sudangrass, which received both the generous organic matter produced by a summer sudangrass cover crop and organic compost for fertilizer, had the highest population of microbes. Most of the other treatments had similar microbial populations. It does not appear that organic management practices per se affect microbial populations. The microbes appear to be responding to increased soil organic matter, regardless of whether synthetic fertilizers or pesticides are applied.

The mechanism to retain organic carbon in soils is related to the amount of clay we have in the soil. The more clay the more the organic carbon retained in the soil. The charged clay surfaces absorb the multi-functional organic molecules providing a substrate where the organic molecules act as bridges to bind other colloids or to retain nutrients. Due to the limited amount of clay in these sandy soils, the amount of organic canon retained was also very limited, the percentage of organic carbon in the samples was below 1% in all cases (Table 2). While all of these would still be considered low organic matter soils, small increases in organic matter of less than 0.5% caused significant changes water retention ability. The %C was highly correlated (r^2=0.85) with saturation percentage (SP) of the soil paste, a measure of the ability of the soil to retain water. Organic matter content did not affect lettuce yield. Marketable yield of melons was correlated with soil organic matter content (r^2=0.66). This relationship can be understood by considering the relationship of BD and Percent Organic Matter (Figure 2). It seems that the root development of cantaloupes was positively affected by the better-developed soil structure (higher porosity, less BD). The improved soil structure resulted from small increases in organic carbon content.

Lettuce yield was directly related to aggregate size (Fig. 3). Aggregate area was also correlated with the roughness of the pores (r^2=-0.65) and with the roughness of the aggregates (data not shown). Roughness seems to be important for the size of the lettuce head. Roughness has been associated in some studies with tortuosity -- the higher the roughness, the more difficulty the water has to go through the soil profile, indicating possible aeration problems may have affected the full growth of the lettuce heads.

In summary, amending a low carbon soil improved yield after two years. The soil had some structural changes that were correlated with improved melon and lettuce yield. Increases in soil microbial populations were also detected as organic carbon was added to the soil

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<u>Tables</u>

Table 1. Effect of cropping system on soil microbial biomass.

Summer cover crop	Management Practice	mg Carbon per g Soil
None	Conventional	0.50a
None	Organic	0.61b
Cowpea	Conventional	0.58b
Cowpea	Organic	0.60b
Sudangrass	Conventional	0.62b
Sudangrass	Organic	0.67c

Table 2. Total organic carbon, sand, silt, and clay percentages, saturation percentage (SP), aggregate area (Aa), pore roughness (R), and bulk density (BD).

OM %	C %	Sand %	Silt %	Clay %	SP %	Aa μm	R	BD g/cm^3
CMC	0.81	78.28	15.47	6.25	25.8	26306	1.22	1.46
CMO	0.94	73.08	19.96	6.97	26.5	28453	1.22	1.47
BGC	0.82	78.28	15.47	6.25	24.4	18697	1.19	1.48
BGO	0.92	74.38	18.12	7.50	24.7	18040	1.18	1.52
CIC	0.78	78.28	16.01	5.71	24.3	36315	1.22	1.63
CIO	0.58	83.48	10.27	6.25	23.0	30555	1.19	1.68
SC	0.72	80.88	12.87	6.25	24.3	40343	1.19	1.62
SO	0.86	81.71	13.29	5.00	24.8	25790	1.14	1.58
BGC	0.81	81.71	12.04	6.25	23.6	21338	1.22	1.45
BGO	0.80	82.98	10.77	6.25	23.6	23559	1.18	1.59
SC	0.71	80.88	12.87	6.25	24.0	18810	1.18	1.52
SO	0.71	84.26	10.03	5.71	23.7	22747	1.19	1.65
CMC	0.70	81.71	13.29	5.00	24.0	25524	1.19	1.73
CMO	0.65	80.88	13.40	5.71	23.1	20247	1.18	1.63
CIC	0.69	82.18	12.82	5.00	23.3	27907	1.20	1.50
CIO	0.68	81.71	12.04	6.25	23.4	28267	1.15	1.60

Key to treatments: First letter refers to summer cover crop (C=Cowpea, BG=Bareground, S=Sudangrass); second or third letter is whether the cowpea was incorporated (I) or mulched on the soil surface (M); the final letter is for Organic (O) or Conventional (C) management practice.

Figures

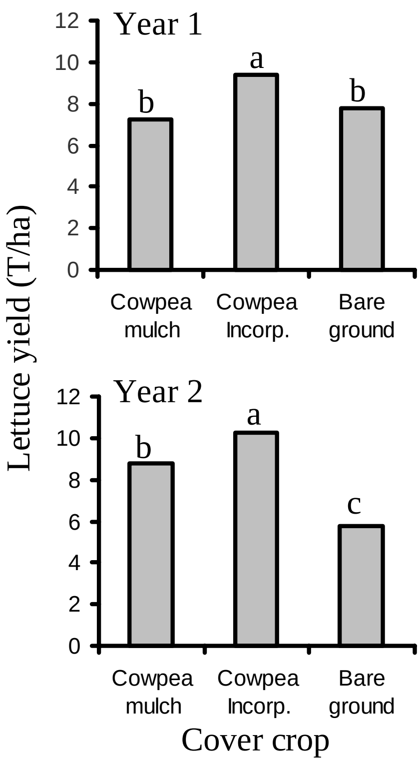

Fig. 1. Lettuce yield response to different summer cover crops.

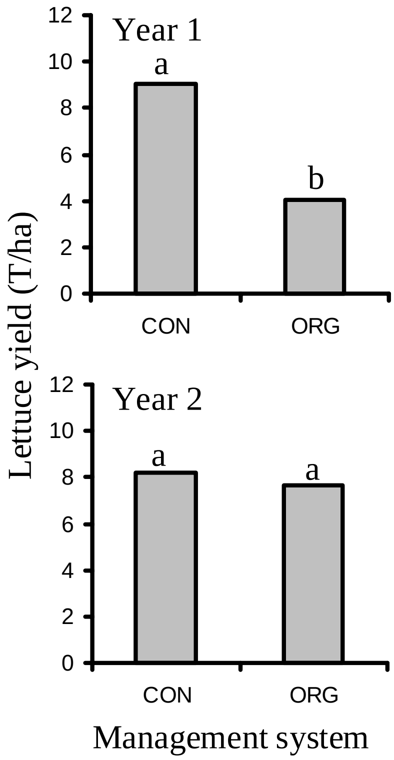

Fig. 2. Fall lettuce yield for conventional (CON) or organic (ORG) management systems.

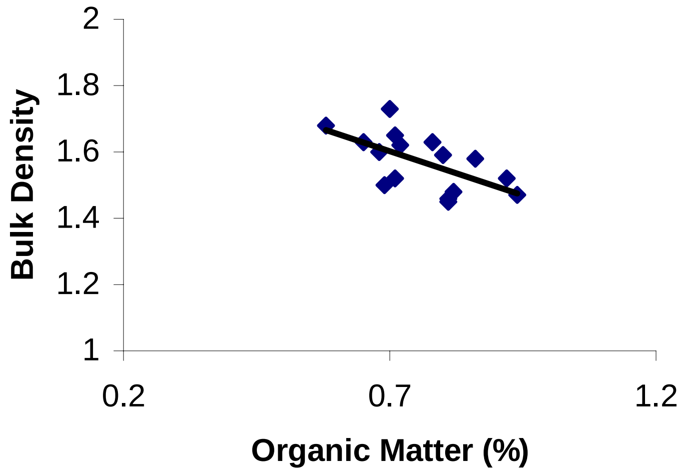

Fig. 3. The decline in bulk density as soil organic matter content increases.

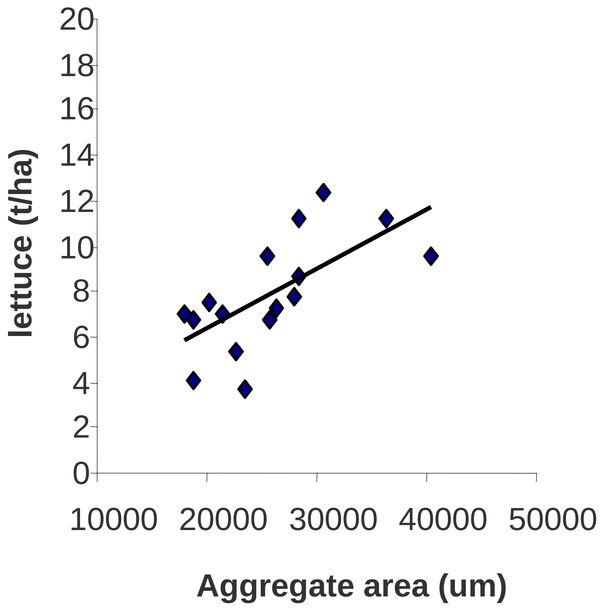

Fig. 4. Lettuce yield increases with soil aggregate size.