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SOIL ACIDIFICATION UNDER ORGANIC FARMING PRACTICES

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ABSTRACT

The organic farming has significant impact on soil fertility, and that includes the soil pH.

We performed a nineteen years study (1994-2013) of pH in an organic cropping system on chernozem loam, a slightly acidic soil with 6.3-6.8 pH in aqueous solution, and a two years study (2012-2013) of pH in an organic and a conventional cropping system on stagni-albic luvisol, a clayey and strongly acidic soil with 5.02-5.03 pH in aqueous solution.

During organic management, the pH of the chernozem loam soil decreased significantly and continuously, until 5.4-6.0, and the soil became moderately acid (pH≤6.0) in the period 2006-2007, after 12-13 years from beginning of the organic management.

The pH in aqueous solution of the stagni-albic luvisol depended on soil management type: in conventional cropping it was maintained in the limits of a strong acid soil (5.35-5.51), but in organic cropping it changed to very strongly acid (pH≤5.00). The content in available aluminium of the stagni-albic luvisol ranged between 29.65 and 44.70 ppm Al in the conventional management and increased to 50.40-83.62 ppm Al under organic management.

According to our results and other similar literature information, the soil acidification is a reality of organic farming. It makes scientific and practical sense to use the pH as indicator of organic management of the soils, because pH represents a central position in chemical and biological processes of the soil and plant growth, and pH measurement is neither difficult nor expensive.

Key words: soil, pH, acidification, organic farming.

INTRODUCTION

The soil acidification is, according to the Department of Environment and Resource Management of Queensland/ Australia (2009), a process through which soil pH decreases over time, but there are no visible signs of this problem. Acidification can occur under natural conditions over thousands of years, with high rainfall areas most affected, as well as over a few years under intensive agricultural practices.

As regards to soil pH under organic practices, Neher (1999), excepting Orange County from 5 studies cited in the Piedmont region of North Caroline, USA and Diepeningen et al. (2006), in the Netherlands on clay and sandy soils, showed lower pH in all organic fields comparative to conventional fields. Davis et al. (2002), in the final report of the project "Long-term organic farming impacts on soil fertility", concludes that annual soil tests revealed a significant decrease (p<0.05 in pH levels in ≥33% of the study fields. Also, Buchan et al. (2009) remarked a significantly lower pH in organic fields on sandy loam/loamy sand soil in Flanders, and Toncea et al. (2012) informed about pH decreasing under accredited organic management on chernozem loam soil.

This paper focuses on the evolution of the pH in soils under accredited organic and conventional farming systems in two different Romanian agro-ecosystems, one with chernozem light acid soil and another one with stagni-albic luvisol strong acid soils, as well as on the exchangeable aluminium evolution in the stagni-albic strong acid soil.

MATERIAL AND METHODS

The studies were located in the organic fields of two Romanian agriculture research units which belong to the Romanian Plain ecosystem – the Research, Innovation and

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Technical Assistance Centre for Organic Agriculture, part of National Agricultural Research and Development Institute (NARDI) Fundulea/Calarasi (44°30'N latitude, 68 m altitude, 10.5°C main air temperature, 571 mm rainfall, and chernozem loam soil with 6.3-6.8 pH in aqueous solution) and the Research and Development Agricultural Station (ARDS) Pitești (44°77'N latitude, 315 m altitude, 9.8°C main air temperature, 679 mm rainfall, and stagni-albic luvisol clayey soil with 5.02-5.03 pH in aqueous solution).

All fields were soil sampled every year in August and September, after harvest of winter and/or spring cereals, legumes or/and industrial and forage crops, before starting organic management, 1994 at NARDI Fundulea and 2012 at ARDS Pitești, and in the last organic management years (2009-2013 at NARDI Fundulea and 2013 at ARDS Pitești). In organic practices, plant residues and no artificial herbicides, fungicides or insecticides were used. In conventional agriculture artificial fertilizers (nitrogen and phosphate applied at 80-100 kg ha^{-1} and 80 kg ha^{-1} respectively), herbicides, fungicides and insecticides were used.

The dried soil samples were analysed – the water pH by the potentiometric method and the exchangeable aluminium, by the Sokolov method.

The soils acidity level is according to classification of the former Soil Conservation Service of The United States Department of Agriculture Natural Resources Conservation Service (1993).

One-sided paired F and P-test was used for the comparisons between organic and conventional soils for studied chemical variables, for loam and clayey soils separately.

Significant P-values are indicated by *($P<0.05$), **($P<0.01$), ***($P<0.001$).

RESULTS AND DISCUSSION

The means and standard errors of water pH in dynamics of organically versus conventionally managed Fundulea chernozem are presented in Table 1.

In 1994, before organic management, the pH of soil from Fundulea varied around 6.16, in the limits for the slight acidic soils.

During organic management, the pH of this loam soil decreased significantly ($F=6.39731$ and $P=0.0041$) and continuously, until 5.4-6.0, and the soil became moderately acid. This pH range is at inferior limits of the optimum pH range for most crops (5.5-7.0).

Table 1. Means and standard errors for measured soil pH grouped according to management type (Fundulea, 1994, 2009-2013)

Year	Management type	Means and standard errors	F	P-value (%)	F crit.
1994	Conventional	6.16 ± 0.142	6.39731	0.004057***	3.105875
2009	Organic	5.96 ± 0.106			
2010		5.82 ± 0.031			
2011		5.65 ± 0.252			
2012		5.75 ± 0.101			
2013		5.68 ± 0.015			

Fitted curve of the pH of soil from Fundulea under the conventional and organic management (Figure 1) confirm the ANOVA results and, in addition, suggest the lowering of the chernozem pH in organic management, the soil turning into moderately acid (pH≤6.0) in the period 2006-2007, after 12-13 years from beginning of the organic management.

The soil acidification of Fundulea loam soil could have occurred because of organic acids produced by the plants and/or organic acids liberated from plant residues incorporated in the soil each year, and/or by crops root activity to take up nutrients, especially phosphorus only from the soil stock, releasing extra H^{+} ions in the soil solution.

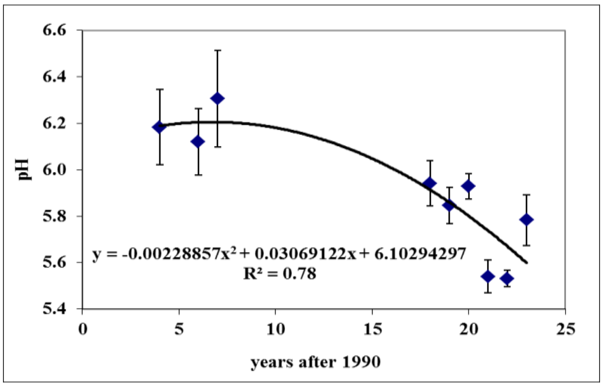

Figure 1. The relationships among the pH of Fundulea chernozem and years under conventional and organic management

According to Table 2, the water pH of Pitești stagni-albic luvisoil depended on soil management type too: 5.35-5.51 in conventional management and 4.85-5.00 in organic management. The pH difference between the Pitești stagni-albic luvisoil management types is very significant (F=89.304 and P=1.71902E^{-06}); the soil acidity has changed from strong acid in conventional farming to very strong acid in organic farming.

Table 2. Means and standard errors for measured soil pH grouped according to management type (ARDS Pitești, 2012 and 2013)

Year	Soil management	Means and standard errors	F	P-value %	F crit.
2012	Conventional	5.35±0.044	89.304	1.71902E^{-06***}	4.066181
	Organic	5.00±0.092			
2013	Conventional	5.51±0.017			
	Organic	4.85±0.044			

The content in available aluminium of the Pitești soil (Table 3) ranged in the 29.65-44.70 ppmAl range at the conventional management and in the 50.40-83.62 ppm Al range at organic management. The significantly higher exchangeable aluminium of organically stagni-albic luvisol (F=8124 and P=2.85E^{-14}) soils may be due to crops root activity to take up nutrients, especially phosphorus only from the soil stock, releasing extra Al^{+3} ions in the soil solution.

Table 3. Means and standard errors for measured soil exchangeable Al grouped according to management type (ARDS Pitești, 2012 and 2013)

Year	Soil management	Means and standard errors	F	P-value %	F crit.
2012	Conventional	29.65±0.427	8124.136	2.85E^{-14***}	4.066181
	Organic	83.62±0.666			
2013	Conventional	44.70±0.265			
	Organic	50.40±0.265			

The aluminium data of Pitești cultivated stagni-albic luvisol corresponds to water pH, because between pH 4 and 6, Al^{3+} reacts with water (H_2O) forming $AlOH^{2+}$, and releasing extra H^+ ions (Sparks, 2003).

The soil acidification can be a visible problem in organic farming according to soil type, after 12-14 years on the chernozem slight acid soils and already in the second year on the strong acidic luvisols.

The lower pH in organic fields comparative to conventional fields in Neher`s studies (1999) in North Caroline/USA and Diepeningen`s et al. (2006) studies in the Netherlands may have been due to chance, but the Buchan`s et al. (2009) study in Flanders, Toncea et al. (2012) in Fundulea, Romania, and the results of the present studies, show that the soil acidification is a reality in organic farming.

On the other hand, the water pH has several features that reinforce its use as indicator of organic soil management. First, many studies, including ours, about soil characteristics of organic and conventional management soils, showed the lowest pH in organic soil management. Second, both macronutrient and micronutrient availability are affected by soil pH. Plants grown on acid soils can experience a variety of symptoms including aluminium (Al), hydrogen (H), and/or manganese (Mn) toxicity, as well as potential nutrient deficiencies of calcium (Ca), magnesium (Mg) and phosphorus (P) (Brady and Weil, 2002). Thirdly, the activity of soil bacteria that fix and convert atmospheric nitrogen into a nitrogen compound is weak or non-existent in acid soils (Borlan & Hera, 1973). Finally, the analysis of the soil water pH is an easy and low cost method.

If further studies will validate these results, it makes sense to use pH as an indicator of organic soil management.

CONCLUSIONS

Soil acidification in organic farming systems is an unexpected reality.

The soil acidification of organic management soils can occur because of three potential phenomena:

- the plants take up mineral nutrients from the soil stock, releasing extra H^+ and Al^{+3} ions in the soil solution;
- organic acids exuded by the plants into the soil, and
- organic acids liberated from plant residues incorporated in the soil.

It makes scientific and practical sense to use pH as indicators of organically managed soils, because pH represents a central position in the soil chemical and biological processes and plant growth and it measurement is not difficult and less expensive. However, further studies of water pH of organic managed soils are necessary.

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