Effect of liquid cattle manure on corn yield, macronutrients' content and uptake and on soil fertility, in comparison to common and recommended inorganic fertilization

E. Samara[1], T. Matsi[1], N. Barbayiannis[1], A.S. Lithourgidis[2]

[1]Soil Science Laboratory, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, 54124, Greece

[2]University Farm, Aristotle University of Thessaloniki, Thermi, 57001, Greece

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Presenting author email: edsamara7@gmail.com

The beneficial effect of liquid cattle (*Bos Taurus* L.) manure on crop yield and growth similar or lower than that of inorganic fertilizers dependent on the manure's macronutrients applied, especially N (Sutton *et al.* 1986). In general, crop availability of manure's N is lower than that of inorganic fertilizers (Beauchamp, 1983, Jokela, 1992) and because of this, manure is usually applied at N rates higher than those of inorganic fertilizers (Evans *et al.* 1977, Sutton *et al.* 1986, Zebarth *et al.* 1996). However, similar crop yield and plant uptake of macronutrients could be obtained after soil application of liquid cattle manure at rates equivalent to inorganic fertilizers (Lithourgidis *et al.* 2007, Matsi *et al.* 2003, 2015). The effects of liquid dairy cattle manure on corn (*Zea mays* L.) yield and macronutrients' content and uptake were studied, in comparison to the common and recommended inorganic fertilization for corn, by means of a five-year field experiment.

The experiment was conducted in a field of the Farm of Aristotle University of Thessaloniki, Greece, during the years of 2009-2013. The size of the experimental plots including the buffering zone was almost 48 m^2 and the experimental design was randomized blocks with four fertilization treatments replicated six times.

The treatments, established in the same plots before sowing each year, were: i) Manure, application of 80 Mg ha^{-1} yr^{-1} (wet weight basis) of liquid dairy cattle manure (excrement plus urine). Based on manure's total N-P-K content, ≈ 250 kg N ha^{-1} yr^{-1}, ≈ 55 kg P ha^{-1} yr^{-1} and ≈ 200 kg K ha^{-1} yr^{-1} were applied. ii) Common inorganic fertilization (used by the farmers in the area), application of N-P fertilization at the rates of 260 kg N ha^{-1} yr^{-1} and 57 kg P ha^{-1} yr^{-1}. iii) Recommended inorganic fertilization, application of N-P-K fertilization at the rates of ≈ 230 kg N ha^{-1} yr^{-1}, ≈ 25 kg P ha^{-1} yr^{-1} or 0 kg P ha^{-1} yr^{-1} and ≈ 180 kg K ha^{-1} yr^{-1}, depending on the results of soil analysis, which was conducted in the beginning of each growing season. iv) Control, no organic or inorganic fertilizers' application.

The same field had been used in a similar fertilization experiment with liquid cattle manure since 1996. Initially (1996-2000) the field was cultivated with winter wheat (*Triticum aestivum* L.) (Matsi *et al.* 2003), then was left to fallow for one year (2001) and subsequently was cultivated with corn (2002-2008) (Lithourgidis *et al.* 2007, Matsi *et al.* 2015). During the corn period, all treatments except the third one (which was application of the common inorganic N-P fertilization with split N application) were similar to the previously mentioned.

During the period of 2009-2013, composite surface soil samples were collected from each plot in the spring of each year before corn sowing, air-dried, ground to pass a 2-mm sieve and analyzed for certain chemical properties. Specifically, pH was determined in water (1:2 soil to water ratio), electrical conductivity was determined in the saturation extract (EC_{se}), Kjeldahl-N was measured (Bremner, 1996) and organic C was determined by the wet oxidation method (Walkley and Black, 1934). Moreover, soil available NO_3-N was extracted with 2 M KCl (Mulvaney, 1996) and determined by ultraviolet spectrometry, P was extracted with 0.5 M $NaHCO_3$, pH 8.5 and determined by the molybdenum blue-ascorbic acid method (Kuo, 1996) and K was extracted with 1 M CH_3COONH_4, pH 7 and determined by flame photometry (Thomas, 1982).

Corn aboveground biomass was collected at the R3 growth stage in each year, was dried at 65 °C and dry aboveground biomass yield was calculated (silage yield). The plant samples were ground and analyzed for Kjeldahl-N and after dry ashing (Mills and Benton-Jones, 1996) for P and K employing the aforementioned methods of the respective analytical determinations, and the macronutrients' plant uptake was calculated. In addition, grain yield was determined from each plot at the end of October.

For each soil or biological parameter determined analysis of variance (ANOVA) was conducted and the LSD test, at $p \leq 0.05$, was used for mean comparisons.

Corn silage and grain yield which were obtained from manure-treated plots significantly increased compared with control and ranged at levels similar to that of the inorganic (common or recommended) fertilization treatments (Figure 1). The N-P-K concentrations in corn biomass were not affected by treatment and throughout all treatments and years their ranges were 7.1-10.3 g kg^{-1} for N, 0.94-2.00 g kg^{-1} for P and 4.5-9.5 g kg^{-1} for K. As for corn yields, similar increases were obtained for the three macronutrients' uptake by corn upon manure or inorganic (common or recommended) fertilization treatments, in almost all years.

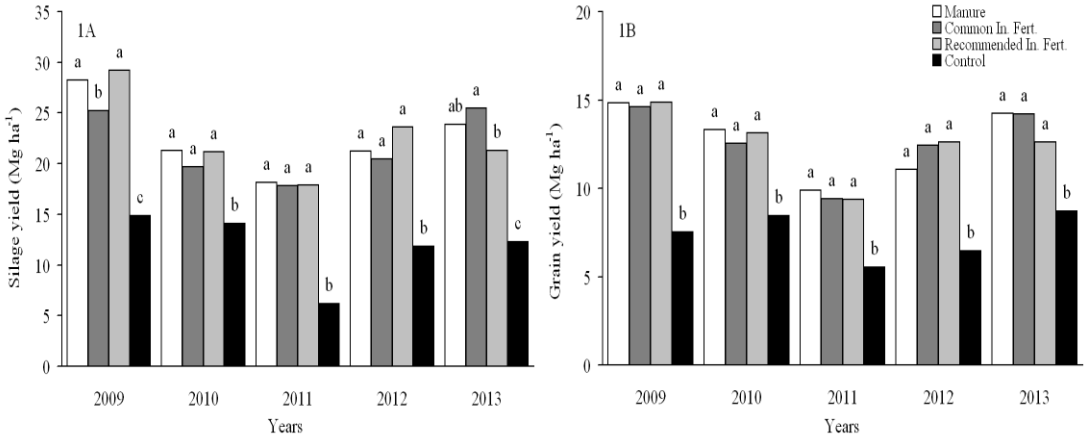

Figure 1. Corn silage (1A) and grain (1B) yield following liquid cattle manure application or the common or the recommended inorganic fertilization the years 2009-2013.
Means indicated with different letters, within each year, are statistically different using the LSD test at $p \leq 0.05$.

Soil pH and EC_{se} remained unchanged and in all treatments and years ranged from 7.9 to 8.5 and from 0.35 to 0.97 dS m^{-1}, respectively. Although a significant increase of soil organic C and total N was observed upon manure's addition in certain years, this increase was not consistent during the whole period of experimentation, and their respective concentration ranges in manure-treated plots were 7.6-11.2 and 0.84-1.24 g kg^{-1}. Soil available NO_3-N and P of manure-treated plots significantly increased compared with control and ranged at levels similar or a little higher than those of the inorganic (common or recommended) fertilization treatments. In, addition consistent increase of soil available K was observed upon the manure application or the recommended inorganic fertilization.

In conclusion, repeated annual applications of liquid cattle manure into the soil, at rates comparable (regarding N) to the common or recommended inorganic fertilization for corn can enhance crop yield and macronutrients' uptake, at levels higher or similar to the inorganic fertilization.

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