

# Use of Manure to Wheat Production in an Argentinean Hapludoll Soil

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## Abstract

Beef cattle feeding operations or feedlots generate large amounts of manure that negatively affect the environment. In order to reach an integrated farming system, setting a final destiny for these wastes not to damage the environment, the use of cattle manure in partial or total replacement of inorganic fertilizers has been evaluated. The study was done in sub-humid, *sandy pampas* region, on an Entic Hapludoll soil. The field experiment was performed using wheat. Four treatments were carried out as follows: a control treatment on the one hand and other three treatments on the other, containing a 116 kg N ha<sup>-1</sup> isodose: Inorganic Fertilization (IF), Manure (M) and a mixture of Manure and Inorganic Fertilizers (M-IF) in equal parts. Results show M-IF treatment as the most efficient one, because it had the highest yield with the least negative effects over the environment.

**Keywords:** Manure; Land application; Soil; Wheat; Environment

## Introduction

Beef cattle feeding operations or feedlots generate large volumes of manure which can negatively impact the environment [1,2]. This residue has a high concentration of nutrients (N, P and K), minerals, trace elements, organic matter and pathogens, among others. Its components can be mobilized by water dynamics and reach into surface or groundwater water sources, deteriorating its quality [3,4].

Using manure in wheat production cropland is an alternative method to reduce feedlot environmental impact [5] and thus to achieve an integrated farming system [6]. Manure provides some of the essential elements for growth and development of crops due to its high nutrient concentration, which can significantly reduce fertilizing costs [4]. Moreover, the increase in organic matter [7] (and thus, moisture retention capacity) improves and maintains the soil properties.

There are international standards and technical procedures on manure fertilization practices. Nevertheless, environmental aspects are conditioning factors over them. Local case studies are essential for developing conceptual models to predict the evolution of these practices under different soil and climate conditions, and thus avoid potential environmental damage. In this context, the aim of this study is to evaluate the use of cattle manure in partial or total replacement of inorganic fertilizers in wheat production and assess its impact on soil properties.

## Materials and Methods

### Study site

The study was carried out in 2010 in a crop-livestock farming system located at 61°32' west longitude and 34°11' south latitude in the Teodelina district, which belongs to the south region of the province of Santa Fe known as the *sandy pampa* (Figure 1) The dominant climate is sub-humid, with an average annual temperature of 16.4°C and an isohydro regimen of 948 mm of annual rainfall [8].

The soil of the site under study has been classified as Entic Hapludoll according to USDA soil taxonomy. This soil has a well drained, sandy loam texture, with high levels of labile phosphorus and organic matter in the topsoil, according to its use track record. A moderate cation exchange capacity value and low concentrations of salts and nitrogen species were also found (Table 1). It is worth to point out that the soils of this region are essentially poor in organic materials and nutrients.

The trial was performed with no-till farming system, and the former crop was corn. The beef cattle manure was collected from a stockpile stored for 4 months. The characteristics of this residue are shown in Table 1.

## Experimental design

Four different treatments were used; three of them maintained an isodose of 116 kg ha<sup>-1</sup> of available N (based on the crop nitrogen requirements to achieve a production of 6700 kg ha<sup>-1</sup>). Treatments were: 1) Inorganic Fertilization (IF) (190 kg ha<sup>-1</sup> urea, 80 kg ha<sup>-1</sup> ammonium sulphate and 170 kg ha<sup>-1</sup> monoammonium phosphate); 2) manure

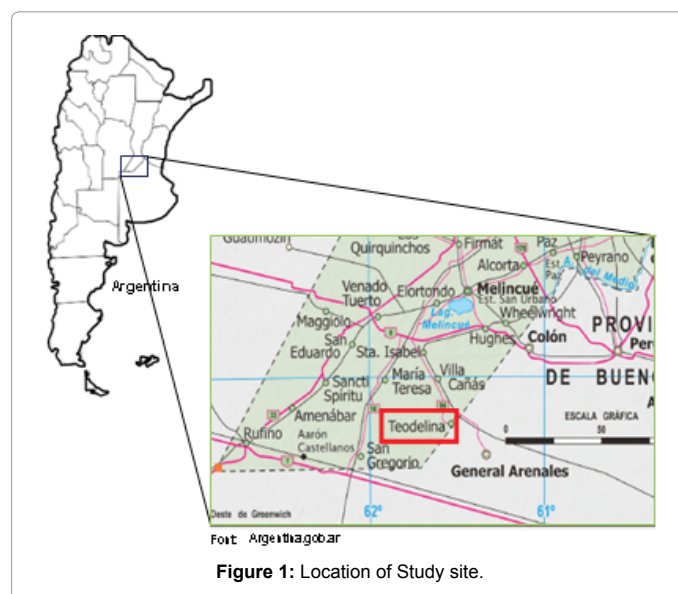


Figure 1: Location of Study site.

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Measured Parameters	Soil		Manure
	0-10	10-20	
Depth (cm)	0-10	10-20	
Gravimetric moisture content (%)	12.5	13.4	31.4
Bulk density (g cm <sup>-3</sup> )	1.3	1.3	
Volumetric water content (%)	16.3	17.2	
Sand (%)	59.1	59.1	
Clay (%)	10.5	10.5	
Silt (%)	30.4	30.4	
Total N (NKj) (%)	0.14	0.10	0.69
N-NO <sub>3</sub> <sup>-</sup> (ppm)	18.1	7.9	0.2
N-NH <sub>4</sub> <sup>+</sup> (ppm)	11.6	12.7	1617.8
Labile P (ppm)	40.7	4.5	1846.5
Total P (%)	0.04	0.03	0.26
pH	5.15	5.81	8.95
Electrical conductivity (dS m <sup>-1</sup> )	0.23	0.13	6.54
Organic Matter (%)	4.5	3.8	17.5
Cation exchange capacity (meq 100 gr <sup>-1</sup> )	12.7	12.1	
<b>Cations:</b>	<i>ExtracTable</i>	<i>Total</i>	
Na <sup>+</sup> (meq 100 g <sup>-1</sup> )	N/D	N/D	10.4
K <sup>+</sup> (meq 100 g <sup>-1</sup> )	0.86	0.73	102.5
Ca <sup>2+</sup> (meq 100 g <sup>-1</sup> )	7.7	9.8	141.1
Mg <sup>2+</sup> (meq 100 g <sup>-1</sup> )	0.96	1.12	227.7
N/D: not detected			

**Table 1:** Physical, chemical and biological properties of soil and manure.

application (M) (40 tn ha<sup>-1</sup>); 3) mixture of manure and inorganic fertilizer (M-IF) (16 tn ha<sup>-1</sup> M and 50%IF); 4) control (C) (soil without any fertilizer application).

Field tasks were made with the facilities machinery and staff. The experiment was conducted in plots of 1300 m<sup>2</sup>. The design was completely randomized with three replicates per treatment. The solid manure [9] was weighed onto a tractor-pulled solid manure spreader and applied to each plot and then, incorporated within 24 hours after application to avoid volatilization losses of nitrogen [10]. Wheat Baguette Premium 11 was used with planting density of 133 kg ha<sup>-1</sup>. Manure and fertilizers were applied 10 days before and during sowing, respectively.

### Sampling and laboratory analysis

Wheat was monitored throughout its cycle. The variables quantified were: ears m<sup>-2</sup>, grain ear<sup>-1</sup>, thousand grain weight and Dry Matter (DM). Three replicates were taken per treatment, and each replicate consisted of 10 single samples of measured variables from each plot. At the end of crop cycle, top soil disturbed samples were collected from the first 10 cm to establish the effects of these practices over its quality. The following variables were quantified by means of standard laboratory methods [11]: pH (measured using potentiometric method, water dilution 1:2.5); electrical conductivity-EC (using conductimetric method, performed in saturated paste); organic matter-OM (determined by loss-on-ignition/combustion method); exchangeable potassium-EK (extracted with 1 M NH<sub>4</sub>Ac pH 7 and measured with atomic absorption spectrometry); total potassium-TK (using wet digestion with oxidizing acids, measured with atomic absorption spectrometry); organic nitrogen-N<sub>Kj</sub> (determined by macro-Kjeldhal method); labile phosphorus- Bray-P and total phosphorus-TP (using Bray-Kurtz 1 extract and wet digestion with oxidizing acids respectively and measured colorimetrically with ammonium molybdate).

### Data Analysis

#### Estimated yield and agronomic efficiency in N and P use

Wheat yield was calculated with data from ears m<sup>-2</sup>, grain ear<sup>-1</sup> and

a thousand grain weight. From the yield results, Nitrogen Agronomic Efficiency (NAE) [12] was calculated as:

$$NAE = \frac{Yield(n) - Yield(c)}{N_{Av}(n)}$$

Where: yield (n) is yield of treatment n, yield (c) is yield of treatment control and N<sub>Av</sub> is available N for crop, applied in treatment n. For treatments with manure, N<sub>Av</sub> was calculated as [13]:

$$N_{Av} = [N\text{-Org}] \times 0.4 + [N\text{-NH}_4^+] \times 0.5 + [N\text{-NO}_3^-]$$

Where: [N-Org] is the concentration of organic N estimated as N<sub>Kj</sub>; 0.4 is a coefficient that indicates the mineralization rate of N-Org from manure in a year [14]; and 0.5 is a coefficient that indicates the availability of N-NH<sub>4</sub><sup>+</sup> from manure in a year [15].

Also, Phosphorus Agronomic Efficiency (PAE) [16] was calculated in order to assess the potential environmental effects of excess application:

$$PAE = \frac{Yield(n) - Yield(c)}{P_L(n)}$$

Where: yield (n) and yield (c) have been already defined and P<sub>L</sub> is available P for crop, applied in treatment n. For treatments with manure, P<sub>L</sub> was estimated as 90% of TP [17].

### Statistical analysis

Descriptive statistic (mean and standard deviation) was applied using statistical software. Under the assumptions of normality and homogeneity of variance, ANOVA model was applied to establish the treatments effect on each variable analysis. Comparison of means was performed using Tukey's test (α=0.05).

## Results and Discussion

### Effects on crop

Treatment effects impacted on the following variables: grain yield, Dry Matter (DM), agronomic efficiency in N use (NAE) and P (PAE) (Table 2). Comparing different treatments, it could be established that plots with fertilization had significantly superior yields than control (C) plots (p<0.05). IF yielded 34% more than C while the increase for M and M-IF was 59%. The lower availability of nutrients present in unfertilized soil could explain these results. Also, yields in treatments M and M-IF were 18% higher (p<0.05) than IF. Similar results were found by Lupwayi et al. [18], who applied manure under a dose of 30 tnha<sup>-1</sup> using wheat in a dry farming system.

Treatments M and M-IF were designed to provide the same dose of available N as in IF. However, yields obtained by them were markedly different from IF (Table 2). Manure as organic matter has the ability to retain water by its numerous functional groups, and it is capable of enhancing crop water status during grain filling stage, generating higher yields. Furthermore, the contribution of other macronutrients such as Ca, Mg and Na, and micronutrients in manure may have influenced these differences.

DM was not as sensitive to different treatments as yield. Only M differed significantly (p<0.05) from the rest with a mean value of 18 tn ha<sup>-1</sup>, being 1.3 times higher than others. Similar results were found by Eghball et al. [1].

Table 2 shows that NAE did not differ significantly (p>0.05) for the two treatments which received organic fertilizers, with a mean value of 24.4 kg of grain kg<sup>-1</sup> of available N applied. This value doubled the NAE of IF treatment (p<0.05). Similar results were found by

Treatments	Grain Yield (kg ha <sup>-1</sup> )	DM (tn ha <sup>-1</sup> )	NAE	PAE
C	4659.9 <sup>a</sup>	12.5 <sup>a</sup>	-	-
IF	6249.9 <sup>b</sup>	13.3 <sup>a</sup>	12.7 <sup>a</sup>	34.7 <sup>a</sup>
M-IF	7235.7 <sup>c</sup>	15.0 <sup>a</sup>	23.8 <sup>b</sup>	42.5 <sup>a</sup>
M	7535.8 <sup>c</sup>	18.2 <sup>b</sup>	25.0 <sup>b</sup>	30.5 <sup>a</sup>

Different letters into each column indicates significant differences ( $\alpha=0.05$ ).  
C: control; IF: inorganic fertilization; M-IF: mix application of manure and inorganic fertilizer; M: manure application; DM: dry matter; NAE: N agronomic efficiency; PAE: P agronomic efficiency

**Table 2:** Treatment effects over crop measured variables.

Vanlauwe et al. [19], who analyzed more than 700 cases. The high NAE value of manure application corresponds to the higher performance achieved, highlighting the beneficial effects of adding manure for crop growth. The lower NAE of IF plots may cause negative effects on the environment (such as pollution of underlying waters with nitrates) due to N excess in soil.

Regarding PAE, no significant differences were found ( $p>0.05$ ), unlike findings by Mujeeb et al. [20]. The absence of such differences can be related to soil nutrient background (Table 1).

### Effects on soil

Treatment effects on soil variables are shown on Table 3. Although statistically significant differences were found in pH, changes below the unit were not sufficiently important considering the normal geochemical changes. The values ranged between 5.25 and 5.92, reaching a mean value of 5.53. Similar results were found by Turner et al. [21].

The greatest value of EC was found in M treatment (0.51 dS m<sup>-1</sup>) and the lowest one in control plots (C) (0.14 dS m<sup>-1</sup>), resulting the first one 3.6 times greater than the second. Also, the value found in M was 2.69 and 2.15 times higher ( $p<0.05$ ) than M-IF and IF respectively. Morari et al. [22] and Turner et al. [21] reported similar variations among the treatments, like in this study. Sorted from lower to higher concentration of soluble salts, the treatments were: C<IF=M-IF<M. Notably, the salinity level reached in M treatment did not exceed the threshold value (0.75 dS m<sup>-1</sup>) established by FAO [23] from which soil begins to be slightly saline. However, increase of salts in M could represent a serious problem considering its effect from a single application to a well-drained soil and under a rainfall regime of 950 mm. Data and literature analysis show that under such management condition, this organic fertilizer behaves as a salinity potential source

when high doses are used ( $\geq 40$  tn ha<sup>-1</sup>). Application doses combining manure and inorganic fertilization (M-IF) may not be as harmful as the exclusive use of manure, taking into account that EC values do not show differences from those resulting from Inorganic Fertilization (IF) (Table 3).

OM, N<sub>kp</sub>, TP, TK variables were statistically less sensitive ( $p>0.05$ ) in different treatments than EC. These results were also found by Chivenge et al. [24] Indraratne et al. [25], Odlare et al. [26] and Riley [27]. The lack of variation could respond to a good soil status according to its use track record and to a dose of manure with concentrations that did not affect the total content of these nutrients.

Regarding EK, only a high dose of manure (40 tn ha<sup>-1</sup>) was capable of changing its concentration (Table 3), similar results were reported by Turner et al. [21]. However, Khodaeijoghan et al. [28] and Eghball et al. [29] showed different behaviors for this variable, possibly due to differences in the initial conditions of soil and manure. K is one of the main causes of soil salinity problems, affecting crop assimilation of other nutrients [30].

Bray-P was sensitive to different treatments, showing a similar behavior to EC. The lowest value was found in the control soil (C treatment) (35.6 ppm), being three times lower ( $p<0.05$ ) than M (Table 3). The latter treatment left postharvest Bray-P concentrations of 1.5 and 2 times greater than M-IF and IF respectively. Over long-term crop rotation, Morari et al. [22] also obtained significant differences similar to those found in this study. The observed variability is mainly characterized by the added amount of P from manure or mineral fertilizer, the degree of mineralization of manure, and the soil's ability to retain this nutrient.

Nevertheless, some important reactions have occurred in the different fractions of soil P (moderate labile P). Performing a phosphorus balance for each treatment (Table 4), it can be observed that 13.5 ppm was found in the restock of P<sub>L</sub> in the control soil. Meanwhile, only 1.3 ppm was replenished from the soil in IF treatment whereas M reloaded 18.6 ppm, twice as much P as M-IF. The gap between these treatments is mainly due to the different concentrations of available P. In organic and mixture plots, more than 93% of P was replenished to soil solution from manure mineralization. In all cases, there was a loss of P from the initial status of the system due to strong nutrients removal of crop.

The replenishment of P from manure mineralization to soil solution

Treatments	pH	EC (dS m <sup>-1</sup> )	OM (%)	Nkj (%)	TP (ppm)	TK (meq100 g <sup>-1</sup> )	EK (meq100 g <sup>-1</sup> )	Bray-P (ppm)
C	5.51 <sup>ab</sup>	0.14 <sup>a</sup>	5.09 <sup>a</sup>	0.103 <sup>a</sup>	495.4 <sup>a</sup>	7.58 <sup>a</sup>	0.83 <sup>a</sup>	35.6 <sup>a</sup>
IF	5.33 <sup>a</sup>	0.19 <sup>b</sup>	5.52 <sup>a</sup>	0.098 <sup>a</sup>	512.5 <sup>a</sup>	7.55 <sup>a</sup>	0.83 <sup>a</sup>	52.5 <sup>b</sup>
M-IF	5.52 <sup>ab</sup>	0.24 <sup>b</sup>	5.19 <sup>a</sup>	0.106 <sup>a</sup>	522.8 <sup>a</sup>	7.59 <sup>a</sup>	0.79 <sup>a</sup>	68.7 <sup>c</sup>
M	5.76 <sup>b</sup>	0.51 <sup>c</sup>	5.40 <sup>a</sup>	0.106 <sup>a</sup>	595.9 <sup>a</sup>	7.64 <sup>a</sup>	1.19 <sup>b</sup>	102.1 <sup>d</sup>

Different letters into each column indicates significant differences ( $\alpha=0.05$ ).  
C: control; IF: inorganic fertilization; M-IF: mixture of manure and inorganic fertilizer; M: manure application; EC: electrical conductivity; OM: organic matter; NKj: N Kjeldhal; TP: total P; EK: exchangeable K; TK: total K

**Table 3:** Treatment effects on soil variables under study.

Treatments	TLP In (ppm)	ELP (ppm)	TLP In - ELP (ppm)	LP Fi (ppm)	P Rep (ppm)	P Balance (ppm)
C	40.0	17.9	22.1	35.6	13.5	-4.4
IF	75.2	24.0	51.2	52.5	1.3	-22.7
M-IF	86.6	27.8	58.8	68.7	9.9	-17.9
M	112.5	29.0	83.5	102.1	18.6	-10.4

C: control; IF: inorganic fertilization; M-IF: mixture of manure and inorganic fertilizer; M: manure; TLP In: Total labile phosphorus at the beginning of crop; TLP In = soil labile P + applied labile P; ELP: Extracted labile P by crop (wheat crop requires 5 kg.tn<sup>-1</sup>); LP Fi: Labile P at the final of crop; P Rep: P Reposition in soil; P Rep= LP Fi - (TLP In - ELP); P Balance = LP Fi-TLP In.

**Table 4:** Labile phosphorus balance for each treatment during wheat crop cycle.

can be seen as a positive aspect. Soils in humid area of the *sandy pampa*, are inherently low in P, so yields can be enhanced by manure application. However, continuous manure applications at a nitrogen-based rate in low adsorption capacity soils (such as in this region) could cause a buildup of P in soil and allow for continued discharge of phosphorus from the cropland. Consequently, P discharges from these areas may not be adequately controlled, adversely affecting the environment should P reach water bodies [31].

## Conclusions

In this work, it was possible to identify the M-IF treatment as the most efficient one, because it showed the highest yield with the least negative effects over soil compared to the other treatments performed. The lowest NAE found in IF and the great accumulation of salts in M, showed potential negative effects of these treatments on the environment.

Our results suggest that applications of manure to sandy loam soil could improve soil water retention and field soil water status, as well as contribute with other macro and micro nutrients, making up for the differences between IF and manure treatment yields.

Evidently, manure represents a potentially significant nutrient source for agricultural production. However, the slower release of residual nitrogen from manures, as well as the buildup of P and K in soil solution, may lead to potential environmental implications under humid conditions. Future research for the recycling of manure in sandy loam soil is needed in order to improve this practice.

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## References

- Eghball B, Ginting D, Gilleyet JE (2004) Residual effects of manure and compost applications on corn production and soil properties. *Agron. J* 96: 442-447.
- García AR, Maisonnave R, Massobrio M, Iorio AF de (2012) Field-scale evaluation of water fluxes and manure solution leaching in feedlot pen soils. *J Environ Qual* 41: 1591-1599.
- García AR, Fleite S, VázquezPugliese D, Iorio AF de (2013) Feedlots and Pollution: A growing threat to water resources of agro-production zone in Argentina. *Environ. SciTechnol* 47: 11932-11933.
- EPA (Environmental Protection Agency) (2000) Enforcement and compliance assurance EPA (2221-A) Profile of the Agricultural Livestock Production Industry, USEPA Protection Agency, Washington.
- EPA (Environmental Protection Agency) (2001) Development document for the proposed revisions to the national pollutant discharge elimination system regulation and the effluent guidelines for concentrated animal feeding operations, USEPA Protection Agency, Washington, 767.
- Gupta V, Rai PK, Risam KS (2012) Integrated Crop-Livestock Farming Systems: A Strategy for Resource Conservation and Environmental Sustainability. *Indian Research Journal of Extension Education* S2: 49-54.
- Shirani H, Hajabbasi MA, Afyuni M, Hemmat A (2002) Effects of farmyard manure and tillage systems on soil physical properties and corn yield in central Iran. *Soil & Tillage Research* 68: 101-108.
- SMN (Servicio Meteorológico Nacional) (2010) Boletín agrometeorológico mensual 1-12.
- Gutser R, Ebertseder T, Weber A, Schraml M, Schmidhalter U (2005) Short-term and residual availability of N after long-term application of organic fertilizers on arable land. *J Plant NutrSci* 168: 439-446.
- Eghball B, Power JF (1994) Beef cattle feedlot manure management. *J Soil Water Conservation* 49: 113-122.
- Page AL (1982) Method of soil analysis. Part 2: Agronomy Series Monograph No 9. ASA, Soil SciSoc Am, Inc. Madison, Wisconsin, USA.
- Wen G, Schoenau J, Charles J, Inanaga S (2003) Efficiency parameters of nitrogen in hog and cattle manure in the second year following application. *J Plant Nutr Soil Sci* 166: 490-498.
- Bulluck III LR, Brosius M, Evanylo GK, Ristaino JB (2002) Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Applied Soil Ecology* 19: 147-160.
- Sweeten JM (1996) Cattle feedlot manure and wastewater management practices for water and air pollution control. In: *Cattle feeding: A guide to management*, Albin, RC, hompson, GB (Ed.) (2<sup>nd</sup> edn), Trafton Printing, Amarillo, US, 62-84.
- Koelsch R, Shapiro C (2006) Determining crop available nutrients from manure. *Neb Guide G1335*, University of Nebraska- Lincoln Extension.
- FAO (Food and Agriculture Organization) (2008) Efficiency of soil and fertilizer phosphorus use. Reconciling changing concepts of soil phosphorus behavior with agronomic information, 123.
- Zhang H, Hamilton DW (2010) Using stockpile feedlot manure as fertilizer. *PSS-2250*, Oklahoma Cooperative Extension Service.
- Lupwayi NZ, Lea T, Beaudoin JL, Clayton GW (2005) Soil microbial biomass, functional diversity and crop yields following application of cattle manure, hog manure and inorganic fertilizers. *Can J Soil Sci* 85: 193-201.
- Vanlauwe B, Kihara J, Chivenge P, Pypers P, Coe R, et al. (2011) Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. *Plant Soil* 339: 33-50.
- Mujeeb F, Rahmatullah, Akhtar J, Ahmad R (2010) Integration of organic and inorganic P sources for improving P use efficiency in different soils. *Soil and Environ* 29: 122-127.
- Turner JC, Hattey JA, Warren JG, Penn CJ (2010) Electrical conductivity and sodium adsorption ratio changes following annual applications of animal manure amendments. *Communications in Soil. Science and Plant Analysis* 41: 1043-1060.
- Morari F, Lugato E, Giardini L (2008) Olsen phosphorus, exchangeable cations and salinity in two long-term experiments of north-eastern Italy and assessment of soil quality evolution. *Agriculture, Ecosystems and Environment* 24: 85-96.
- FAO (Food and Agriculture Organization) (2006) Guidelines for soil description (4th edn.), FAO of the United Nations, Rome, 109.
- Chivenge P, Vanlauwe B, Six S (2011) Does the combined application of organic and mineral nutrient sources influence maize productivity? A meta-analysis. *Plant Soil* 342: 1-30.
- Indraratne SP, Hao X, Chang C, Godlinski F (2009) Rate of soil recovery following termination of long-term cattle manure applications. *Geoderma* 150: 415-423.
- Odlare M, Pell M, Svensson K (2008) Changes in soil chemical and microbiological properties during 4 years of application of various organic residues. *Waste Management* 28: 1246-1253.
- Riley H (2007) Long-term fertilizer trials on loam soil at Møystad, south-eastern Norway: Crop yields, nutrient balances and soil chemical analyses from 1983 to 2003. *ActaAgriculturaeScandinavica Section B-Soil and Plant Science* 57: 140-154.
- Khodaeijoghani A, Ghalavand A, Aghaalikhani M, Gholamhoseini M, Dolatabadian A (2010) Comparison among different integrated nutrition management for soil micro and macro elements after winter wheat harvesting and yield. *Nutr Sci Biol* 2: 107-111.
- Eghball B, Shanahan JF, Varvel GE, Gilley JE (2003) Phosphorus management: Reduction of high soil test phosphorus by corn and soybean varieties. *Agron J* 95: 1233-1239.
- Hao X, Chang C (2003) Does long-term heavy cattle manure application increase salinity of a clay loam soil in semi-arid southern Alberta? *Agriculture, Ecosystems and Environment*. 94: 89-103.
- James R, Eastridge ML, Brown LC, Elder KH, Foster SS, et al. (2006) Ohio Livestock Manure Management Guide. OSUE (Ohio State University Extension). Bulletin 604.