Scientific Paper

Effect of manure on the soil and the soybean [*Glycine max* (L.) Merr.] crop

Pedro Cairo-Cairo[1] and Ubaldo Álvarez- Hernández[2]

[1]*Universidad de Atacama, Centro Regional de Investigación y Desarrollo Sustentable de Atacama (CRIDESAT) Copayapu 485, Copiapó, Chile*
[2]*Universidad Central de Las Villas, Facultad de Ciencias Agropecuarias, Villa Clara, Cuba*
E-mail: pedro.cairo@uda.cl

Abstract

The study was conducted in the Agricultural Research Station of the Central University Marta Abreu of Las Villas –Villa Clara, Cuba–, on a moderately washed soft Brown soil, in order to evaluate the effect of different doses of decomposed cattle manure on the physical and chemical properties of the soil, the soybean yield and the populations of pentatomids. Two soybean varieties were planted: Incasoy-27 and Incasoy-35, at a distance of 0,40 m x 0,05 m which formed the two experiments. The treatments were: T1.- Control without application of manure; T2.–decomposed cattle manure 4 t ha^{-1}; T3.- decomposed cattle manure 8 t ha^{-1} with four replicas each. The following physical and chemical soil properties were evaluated: structure factor, stable aggregates, permeability, pH, organic matter, assimilable phosphorus and potassium. The decomposed manure had effect not only on the soil, but also on the control of the population of pentatomids. The application of decomposed manure produced a significant increase in aggregation, with a category change from regular (52,96 %) to good (66,95 %). The use of decomposed manure in interaction with the soybean crop significantly increased the OM of the soil during a short period of time, which went from low (2,5 %) to moderate category (3,7 %). Likewise, the application of organic matter significantly decreased the population of pentatomids in the soybean crop.

Keywords: organic amendments, physical-chemical soil properties, yield

Introduction

One of the most important characteristics of the organic amendments of the soil is their ability to stimulate the complex of beneficial microorganisms that help to maintain the potential and pathogen pests controlled (Ramos-González *et al*., 2013; Passos *et al*., 2014). The manures from animals and the crop residues constitute a key element in ecological agriculture systems (Larney and Angers, 2012; Penha *et al*., 2012).

Manure is a valuable resource that allows to complete the nutrient cycle and which causes a large part of the nitrogen fixed by legumes and harvested as forage return to the soil, where it will be available again for the subsequent crops (Ren *et al*., 2014). The objective of its application in ecological systems is to ameliorate the biological and physical-chemical properties of the soil, besides being important as energy and nutrient source for the edaphic ecosystem.

Regarding the nutrient concentrations in the plants, their relation with the occurrence of some affectations by pests has been described (Nicholls and Altieri, 2008); hence an unbalance in nutrition can affect the plant growth rate and speed to defend themselves from the attack of pathogens. In that sense, there are several studies that report the additive effects of fertilization and the use of fungicides for the control of late-cycle diseases, and even some which suggest the occurrence of synergic response among treatments (Miguez, 2005).

The cultivation of soybean [*Glycine max* (L.) Merr], the main oil plant worldwide due to its high percentage of protein (35-50 %) and oil (15-25 %), which constitutes a cheap and high-quality source of protein for feeding cattle and men (Romero *et al*., 2013; Temple *et al*., 2013; Dlamini *et al*., 2014; Pegoraro *et al*., 2014), is not free from these affectations. Its yields can be increased if adapted varieties, good management practices, as well as an adequate control of pests and diseases, are used; because it is known that almost half a hundred insects attack soybean throughout the world and damage it from its planting to its establishment, although some of them are not specific (Temple *et al*., 2013).

Taking into consideration that there are few antecedents related to studies that integrate the use of organic manures and their effect on the soil-soybean yield-populations of insects of the Pentatomidae family, reported by Ramos *et al*. (2013) as one of

the most damaging pests in soybean, the objective of this study was to evaluate the effect of different doses of decomposed cattle manure on the physical and chemical properties of the soil, the crop yield and the populations of pentatomids.

Materials and Methods

Characteristics of the study area. The study was conducted at the Research Station Álvaro Barba Machado, belonging to the Central University Marta Abreu of Las Villas –Villa Clara, Cuba–. The soil is classified as moderately washed soft Brown soil (Hernández, 2006), and according to the American Soil Taxonomy it is within the Inceptisol order. The study area is located at 22º 41' 33" North latitude and 80º 16' 75" West longitude. Its soils are carbonated, very clayey, with undulated to flat topography, and they receive 1 300 mm of annual rainfall.

Treatments and design. Two trials were conducted with the same treatments, but with different soybean varieties: Icasoy-27 and Incasoy-35; they were: T1: control without manure application; T2: decomposed cattle manure, 4 t ha^{-1}; T3: decomposed cattle manure, 8 t ha^{-1}.

Each treatment had four replications, for a total of 12 plots per trial, which measured 10 m long x 5 m wide. Planting was performed at a depth of 3 cm and distance of 0,40 m x 0,05 m. A randomized block design was used. The effect on the soil and its relation with the yield and the population of pentatomids were evaluated, and the performance of soybean varieties was not included.

The manure used came from an area covered by vegetation and was subject to decomposition for a year; its chemical composition is shown in table 1.

Soil sampling and analysis. The sampling was made at a depth of 0-20 cm; four replicas were taken per treatment, for a total of 24 samples. The chemical and physical analyses included:

- pH (H_2O) and (KCl): by the potentiometric method, with a soil-solution ratio 1:2,5.
- assimilable P_2O_5 and K_2O: according to Oniani (1964), using an extractive solution of H_2SO_4 of 0,1N. Phosphorus was determined by colorimetric analysis and potassium, through flame photometry.
- organic matter: by colorimetric analysis, according to Walkley and Black (1934).
- permeability coefficient (log_{10} k): according to the method proposed by Henin *et al.* (1958).
- structure factor, % (SF): according to Vageler and Alten (1931).
- stable aggregates, % (SA): through the method suggested by Henin *et al.* (1958).

Yield evaluation. Four plants were selected per replica, for a total of 16 plants per treatment. As yield components, the number of pods per plant and the weight of grains per plant (g) were evaluated.

Evaluation of the number of pentatomids. After the two soybean varieties were planted and the manure was applied, the number of southern green stink bugs (*Nezara viridula*) which had incidence on the crop in the different treatments was quantified through the direct observation method.

Statistical analysis. The professional program package Statgraphics Centurion v. 15 Romano 2006 on Windows was used. Simple classification ANOVA was applied with the mean comparison test (Duncan, 1955) and curve adjustment. The entire data base with the two experiments and also the individual analysis by experiment were considered for some statistical analyses.

Results and Discussion

Effect of decomposed manure on some physical and chemical properties of the soil

Table 2 shows the influence of the application of decomposed manure on the structural status of the soil. The stable aggregates as well as the structure factor and permeability significantly increased with regards to the control. With the application of 8 t ha^{-1} of manure a better structure was achieved. The indicator that best showed the effect was structure, which went from regular category in the control (58 %) to good in T3 (71 %), based on the criteria expressed by Cairo and Reyes (2016).

Cairo *et al.* (2012), when summarizing the effects of different organic and mineral fertilizers, reported the important contribution of compost to the

Table 1. Chemical composition of decomposed cattle manure.

Indicators (%)									
OM	CZ	C	N	P	K	Ca	Mg	C:N	pH
26,22	73,78	15,21	1,48	0,76	1,15	2,26	0,73	10,27	6,68

Table 2. Influence of treatments on some physical properties of the soil.

Treatment	Permeability (Log_{10} k)	SF (%)	SA (%)
T1	1,90[b]	58,50[c]	50,96[c]
T2	2,16[b]	68,43[b]	60,13[b]
T3	2,46[a]	71,38[a]	61,95[a]
SE ±	0,086	0,538	0,495

a, b, c: means with different letters in the same column differ at $p < 0,05$ (Duncan, 1955).

structural status of the soil. The integrating action of soybean as a legume and the organic fertilizer facilitated the conditions for high biological activity, which determined the quality of the formed humus and, thus, the soil aggregation in a short time period (four months).

The most general laws of agroecosystems, and specifically biochemical processes, influence the physical properties through the formation of aggregates and biopores, as well as of the biostructure in which the soil bacteria and fungi participate (Delgado *et al*., 2012; Zhang *et al*., 2012; Socarras, 2013). The loss of the physical properties produces soil compaction and, consequently, water- and air-impermeable crusts are formed on the surface, which affect fertility (Cairo *et al*., 2012).

The pH in KCl and the pH in water did not differ significantly with the different manure doses and were maintained within the neutral range (table 3). In the case of organic matter, increases were shown with regards to the control without fertilization. In this indicator an important quantitative change was achieved when 8 t ha^{-1} of decomposed manure were applied, because it exceeded 1 % of increase. The studies conducted by Balemi (2012), Cairo *et al.* (2012) and Larney and Angers (2012) reaffirm these results. On the other hand, according to the criteria expressed by López *et al*. (1981), OM went from the low category in the degraded soil (T1) to the moderate one in the ameliorated soil with organic fertilizer (T2, T3).

The application of 8 t ha^{-1} of manure produced significant increases of assimilable phosphorus and potassium with regards to T1; these nutrients are not yield limiting factors under the conditions of the study, because of the excessive fertilization for years. Larney and Angers (2012) stated that organic fertilizers of animal origin substantially improve the physical and chemical properties of the soil; while Verde *et al*. (2013) indicated that the use of manure alone or combined with mineral amendments can be a solution to increase the absorption of N and soybean yields.

Effect of the treatments on the yield and the population of pentatomids

The application of 8 t ha^{-1} of decomposed manure (T3) significantly increased the number of pods per plant and the weight of grains per plant, as well as the yield, with regards to the control without fertilizer. The yield gradually increased with the doses of organic fertilizer, from 2,04 to 3,18 t ha^{-1} (table 4). These results are in correspondence with the organic matter level and aggregation of the soil achieved. Pegoraro *et al*. (2014) stated that the soybean yield increased in 17 % with the application of ecopost, and the weight of 1 000 grains decreased ($p < 0,05$); while the grain quality was maintained. Degraded soils, with low OM contents and compaction problems, will have lower yield than those subject to good management, with incorporated grasses, high OM contents and high cover of stubble on the surface (Cairo *et al*., 2012).

As the OM increased a significant decrease of the populations of pentatomids occurred, and the

Table 3. Influence of the treatments on some chemical properties of the soil.

Treatment	pH (H_2O)	pH (KCl)	OM (%)	P_2O_5 (mg100 g^{-1})	K_2O
T1	7,14[a]	6,53[b]	2,58[c]	31,64[b]	54,65[b]
T2	7,14[a]	6,80[ab]	3,18[b]	32,15[ab]	60,06[b]
T3	7,13[a]	6,90[a]	3,70[a]	35,23[a]	72,50[a]
SE=±	0,021	0,096	0,05	0,97	2,43

a, b, c: means with different letters in the same column differ at $p < 0,05$ (Duncan, 1955).

Table 4. Yield and population of pentatomids.

Treatment	Pods/plant	Grains (g)	Insects/plant	Yield (t ha^{-1})
T1	9,00^{c}	2,40^{c}	8,00^{c}	2,04^{c}
T2	14,00^{b}	3,00^{b}	6,00^{b}	2,88^{b}
T3	19,00^{a}	4,50^{a}		3,17^{a}
SE ±	1,130	0,139		0,015

a, b, c: means with different letters in the same column differ at $p < 0,05$ (Duncan, 1955).

best results were obtained with the application of 8 t ha^{-1} of decomposed manure. In studies without the use of organic fertilizers, Marrero (2005) observed a progressive development of the populations of pentatomids. It could be observed during this research that the application of 8 t ha^{-1} of decomposed manure not only had effect on the soil and the crop growth and yield, but also on the population of an important pest (pentatomids) in the soybean crop (Nicholls and Altieri, 2008; Ramos-González *et al*., 2013; Usman, 2015).

Relations between the soil properties, yield and populations of pentatomids

The OM content had high influence on the yield components and the populations of pentatomids (table 5; figs. 1 and 2). Relation was found between the OM, yield components (number of pods and weight of the grains) and yield. The organic matter favors the physiological functions in the plant, based on creating in the soil better conditions of nutrient, water and air assimilation (Boudet *et al*., 2015). There was a negative relation between the OM content and the population of pentatomids (fig. 2). Ramos-González *et al*. (2013) obtained similar results in the bean crop when applying *Rhizobium* and compost. Any factor that affects plant physiology (for example, fertilization) can enhance the resistance to pest insects. The responses of crops to fertilizers, such as changes in the growth rates, accelerated or delayed maturity, size of some plant parts and hardness or weakness of the cuticle, can indirectly

Table 5. Correlations among some studied indicators.

Correlation	Regression equation	R^2	N
OM % x number of pods	P = -14,8525+8,9978*OM	72,27	24
OM % x grain weight (g)	Grain = -2,0067 + 1,6434*OM	80,59	24
OM % x yield t ha^{-1}	Yield = 1/(2,2834 – 0,5376*OM)	98,31	12
Aggregates x yield t ha^{-1}	Yield = 4,9598 – 199,419*SA	95,21	12
OM % x number of insects	Insects = 22,499 – 5,4769*OM	67,00	24

P: Pods

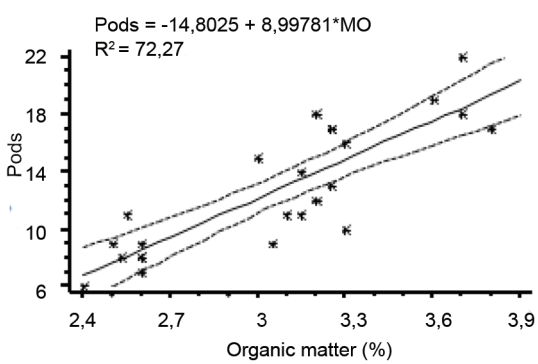

Figure 1. Relation between organic matter (%) and number of pods (plant).

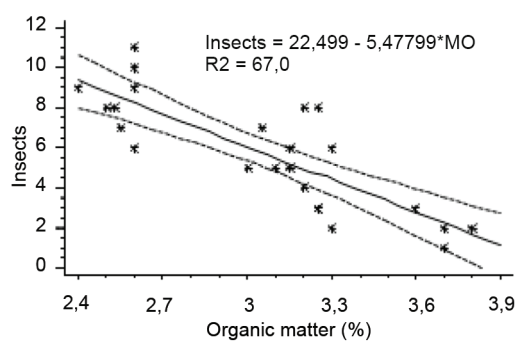

Figure 2. Relation between organic matter (%) and number of pentatomids (plant) in the soybean crop.

influence the success of pest insects to utilize the host plants. The effect of fertilization practices on plant resistance to the attack by insects can be mediated by changes in the nutritional contents of the crops (Nicholls and Altieri, 2008). According to Santana Souza *et al*. (2013), insecticides are used as a control method; however, these products cause environmental unbalance and pest resistance.

Conclusions

The application of decomposed manure originated a significant increase in aggregation, and a change of category was achieved in the soil from regular (52,96 %) to good (66,95 %). The manure in interaction with the soybean crop significantly increased the soil OM during a short time period, which went from the low (2,5 %) to the moderate category (3,7 %). A close relation was found among OM, soil aggregates and plant yield. The application of OM significantly decreased the population of pentatomids.

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