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EFFECT OF *Canavalia ensiformis* (L.) ON PHYSICAL PROPERTIES OF DIFFERENTIATED FLUVISOL SOIL IN SANTIAGO DE CUBA

Efecto de *Canavalia ensiformis* (L). en propiedades físicas de un suelo fluvisol diferenciado en Santiago de Cuba

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ABSTRACT. Soil is one of the most important natural resources for life. Food production depends on a percentage of use of this resource, which is continuously degraded as result of an incorrect handling and exploitation. *Canavalia ensiformis* is among the plants most used as green manure. In order to evaluate the effect of different ways of this legume on the fertility of a Differentiated Fluvisol soil, the research was carried out at (UBPC, Basic Unit of Cooperative Production) at Huerto Santiago 2, at Santiago de Cuba municipality. The experiment was planted in June 2014 and 2015 with a planting distance of 0,75 m between rows and 0,25 m between plants. A design of blocks was used at random, with four treatments and four replicas: an absolute control that represented the natural fertility of the soil; a treatment where the canavalia was established until 80 days, was cut and left the biomass on the ground; another where the canavalia at 80 days was cut and incorporated the biomass to the soil; and other where the legume remained standing on the ground. The apparent density, porosity and soil hygroscopic moisture were analyzed as well as the quality through the visual evaluation method. The results evidenced a positive effect of the different treatments in the physical evaluated properties and the quality of the ground, being superior when the green fertilizer was incorporated to the soil or it was incorporated permanently.

Key words: green manure, fertility, legume, nagement

RESUMEN. El suelo constituye uno de los recursos naturales más importantes para la vida. La producción de alimentos depende del uso de este recurso, que se degrada continuamente como resultado de un incorrecto manejo y explotación. *Canavalia ensiformis* se encuentra entre las plantas más empleadas como abono verde por las mejoras que ofrece en las propiedades del suelo. Con el objetivo de evaluar el efecto de diferentes manejos de esta planta en la fertilidad de un suelo Fluvisol Diferenciado, se desarrolló la presente investigación en la Unidad Básica de Producción Cooperativa (UBPC) Huerto Santiago 2, en el municipio Santiago de Cuba. El experimento se sembró en junio 2014 y 2015 con una distancia de siembra de 0,75 m entre hileras y de 0,25 m entre plantas. Se empleó un diseño de bloques al azar, con cuatro tratamientos y cuatro réplicas: un testigo absoluto que representó la fertilidad natural del suelo; con tres tratamientos con Canavalia uno establecida hasta los 80 días, se cortó y se dejó la biomasa sobre el suelo; otro a los 80 días se cortó e incorporó la biomasa al suelo; y el ultimo la leguminosa se mantuvo permanente en el suelo hasta los 120 días. Se analizó la densidad aparente, la porosidad y la humedad del suelo, así como la calidad mediante el método de evaluación visual de indicadores. Los resultados mostraron un efecto positivo de los diferentes tratamientos en las propiedades físicas evaluadas y la calidad del suelo, siendo superiores cuando se incorporó el abono verde al suelo o se mantuvo de forma permanente.

Palabras clave: abonos verdes, fertilidad, leguminosa, manejo

INTRODUCTION

Soils are deteriorating rapidly due to erosion, depletion of nutrients, loss of organic carbon, soil sealing and other threats, but this can be reversed whenever initiatives are taken to promote sustainable management practices and the use of appropriate technologies (1).

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The green fertilizers are defined as plants that are sown in rotation or interspersed with crops of particular interest, in order to provide them with nutrients, maintain or improve the organic matter contents of the soil over time; they allow protecting, recovering, contributing and improving the biological, physical and nutritional conditions of the soil (2). The use of green fertilizers has shown its potential in increasing the productivity of crops and their sustainability. The planting of these in cultivated agricultural areas improves the properties of the soil, minimizes its deterioration and restores the lost fertility, all of which directly affects the increase of the agricultural yields (3).

The use of *Canavalia ensiformis* (L) as a green manure can improve the physical properties of the soil such as porosity, volume density and the formation and stability of the aggregates (4). It is a legume that fixes large amounts of nitrogen by symbiosis, and provides adequate soil conditions (5). It is considered the best legume to face frequent droughts in a given region, this species is extremely resistant to dry periods and deteriorated soil, produces about 60 t ha^{-1} of biomass, fixed up to 240 kg ha^{-1} of nitrogen.

In Cuba, from the 80s, continuous agriculture, the use of aggressive farming system, and monoculture caused the deterioration of the physical, chemical and biological properties of the soils and the increase of the surface affected by erosive processes and degradation (6).

The Fluvisol soil under study has a low content of organic matter, with a level of laminar erosion, and impoverishment of fertility in some of its areas; the application of inadequate management practices together with the effects of climate change contribute to accelerate the degradation processes of the same, affecting its fertility and limiting productivity. That is why this work aimed to evaluate the impact of the use of *Canavalia ensiformis* in some physical properties of a Differentiated Fluvisol soil, in Santiago de Cuba municipality.

MATERIALS AND METHODS

The experiment was carried out under rainfed conditions, in an area of the UBPC Huerto Santiago 2, located in the Santiago de Cuba municipality, on a Differentiated Fluvisol soil (currently Agrogenic Fluvisol) (7) with more than 40 years of exploitation.

Canavalia ensiformis was used as a green manure, and cover crop that was sown in June 2014 and 2015, whose seeds came from the National Institute of Agricultural Sciences (INCA). No biofertilizers or biostimulants were used.

A randomized block design was used, with four treatments and four replications:

Treatment I (Sn): absolute control, natural soil condition.

Treatment II (Cs / i): the canavalia was established for 80 days, the biomass was cut and left on the soil.

Treatment III (C / i): the canavalia was established for 80 days, the biomass was cut and the soil was incorporated 72 hours after the cut, at a depth of 0.15 cm.

Treatment IV (C / p): the legume was maintained permanently.

The effect of the treatments on the physical characteristics of the soil was determined from two soil samples, carried out at 0 days before sowing and at 120 days after the different management of *Canavalia ensiformis* was established. Five samples of soil (formed by subsamples) at the depth of 0-20 cm, diagonally (zigzag) were taken in each replica with an agrochemical auger.

The physical variables were determined according to the corresponding branch rules. The apparent density was determined by the method of cutting cylinders (8). The porosity and hygroscopic humidity were evaluated by gravimetry; the wet weight of the soil samples was recorded and then dried at 105 ° C for 24 hours to obtain the dry weight thereof. The percentage of humidity was also calculated (9).

The data obtained were compared by means of variance analysis (ANOVA) and the significance between means was determined by the Duncan test for $p \leq 0.05$.

The soil quality was also evaluated at 120 days, by means of the method of visual evaluation of the indicators (10,11). This method considers the visual evaluation of ten indicators related to physical properties (texture, structure, consistency, color, porosity, surface crusts and cover, presence of earthworms, waterlogging and erosion).

The result in each of the evaluated indicators was obtained considering the values in each treatment per replica, the average was determined and multiplied by the correction factor of each visual value that varies from 1-3; then they are added together and the final value is the visual quality index of the soil for each treatment. From the result of the indicators, the soil quality index is obtained, which establishes a range of: (0-15 Poor); (15-30 Moderate); (> 30 Good).

Compared the results according to the range exposed by the methodology; the visual analysis carried out established the incidence of the visual indicators in the quality of the soil between treatments. The data processor Microsoft Excel, version 10 for Windows system AMIBA was used.

RESULTS AND DISCUSSION

The analysis of apparent density, porosity and soil moisture before planting and at 120 days after it is shown in the Table 1.

Table 1. Behavior of the apparent density, porosity and moisture of the Fluvisol soil at 0 and 120 days of established *Canavalia ensiformis*

Moment	Treatments	Porosity (%)	Gravimetric humidity (%)	Apparent density ($Mg\ m^{-3}$)
0 days	Sn	53,0 d	10,7 e	1,26 a
	Sn	53,2 d	13,04 d	1,24 a
	Cs/i	54,1 c	16,80 c	1,21 ab
120 days	C/i	56,3 b	17,80 b	1,18 b
	C/p	57,0 a	18,90 a	1,16 b
	X	54,6	15,4	1,20
	CV (%)	0,11	0,29	1,65
	ES (x)	0,041***	0,032***	0,014*

*Means with different letters in the same column differ from each other according to Duncan test for p≤0.05. Sn: Control, Cs/i: canavalia without incorporation, C/i: incorporated canavalia, C/p: permanent canavalia

The values of the control soil where the legume (Sn) was not planted were maintained in a similar way in the two evaluated moments, except in the humidity that had an increase to 120 days, with results inferior to the treatments where the canavalia was cultivated for porosity and humidity, not being the apparent density results.

However, at 120 days there is a change in the three variables analyzed with the use of canavalia. The porosity and humidity of the soil increase when the legume is still not incorporated, an increase that becomes more evident if the legume is incorporated and especially if it is maintained permanently. The apparent density, on the other hand, did not differentiate between natural soil and soil without incorporating canavalia, and decreased when the plant was incorporated or permanently maintained. An optimum apparent density for this soil is a range of 1.10 to 1.60 Mg m^{-3} (12), so the decrease found with the use of canavalia means an improvement in the soil due to decompaction.

Other authors have found a positive effect on the physical properties of the soil when crops such as green fertilizers are used, and report that these crops reduce evapotranspiration, the incidence of high temperatures and therefore increase soil moisture (13-15).

Similar results were obtained when using *Mucuna pruriens* as a cover crop, where increases of 20 % in the water content of the soil were obtained (16). The use of rye (*Secale cereale*) as a cover for a soybean crop increased the volumetric moisture content of the soil by 21 % (17).

Other works add that the “organic padding” formed by the decomposition of green manure, reduces evaporation and favors the infiltration of water in the soil profile (18). The aggregation of the soil particles is favored and their stability against the water factor is improved, while at the same time they increase the porosity (19).

The use of canavalia in a red ferralitic soil in Mayabeque modified the porosity, valued high to the depth of 0 to 20 cm; what improved the structure of the soil by allowing the relationship air-water was better in it; the density of all the treatments where it was present also decreased, which was attributed to the fact that the root had a thickness in the first 20 cm of 1 to 2 cm and reached a depth of 50 to 60 cm, which caused a tillage effect biological (4).

The physical properties of the soil are not always related to its quality and efficiency in the sustainability of the productions. Given that there are physical properties that vary in the short term and are difficult to measure quantitatively, but not qualitatively (10), being able to evaluate them provides a more complete evidence of the result achieved in the transformation and modification that occurred in the soil. The analysis performed on the soil at 0 days of the test is presented in Figure 1.

The soil was characterized by a low grain texture, with cracks, dominated by large blocks, dense, in the form of clods, with very few fine aggregates, no macropores and predominance of micropores of brownish yellow color (10.0 YR 6/6), the abundance and color of the mottle of 1 % in the moderate condition, this indicates good aeration in the soil. There was no presence of worms; with a poor waterlogging; crust and moderate surface coverage; water erosion in laminar form of moderate predominance. This soil was classified as Poor, with an 8 quality index.

Figure 2 shows the evolution of these visual indicators at 120 days, after implementing the different treatments.

The soil without canavalia at 120 days (Sn) showed characteristics similar to the control (0 days). It maintained the brownish yellow color (10.0 YR 6/6) and similarly the rest of the indicators were maintained when reaching a quality index of 13 rated in the same condition, Poor.

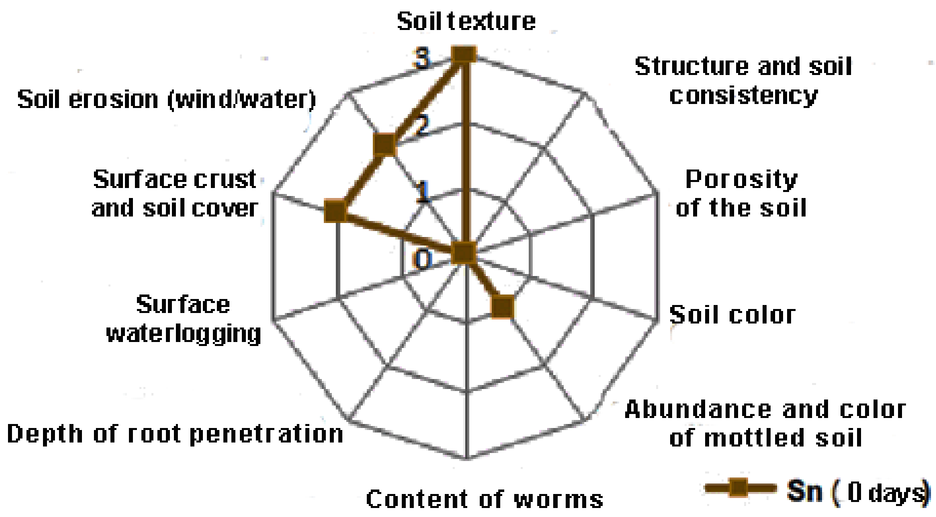


Figure 1. Fluvisol soil visual indicators at 0 days

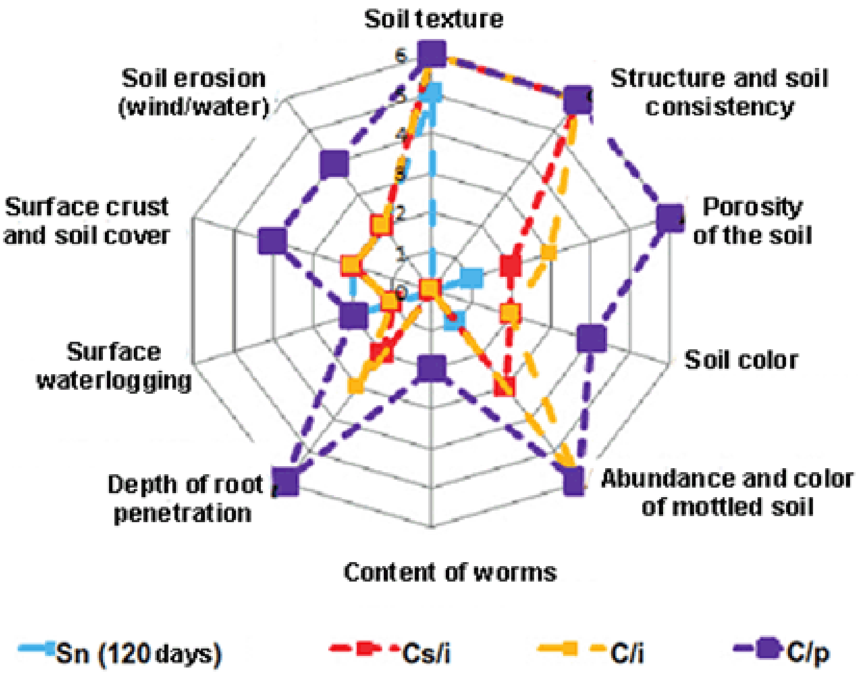


Figure 2. Visual indicators of Fluvisol soil quality at 120 days

The treatments where the canavalia was used without incorporating (Cs/i) and incorporated (C/i) showed similar behaviors, with an improvement in the soil condition to moderate also, granular texture, few cracks; the structure and consistency with a significant proportion (50 %) of lumps terrones and fine friable aggregates; porosity (with presence of macro and micropores) and moderate compaction.

The soil acquired a stronger color with respect to the control being the yellowish brown color for (Cs/i) (10.0 YR 5/6) and brown (C/i) (10.0 YR 4/3); not so for the indicator abundance and color of mottle. Both the presence of earthworms and the effective depth of the roots (0.55 and 0.59 cm), the surface waterlogging and the crust and superficial coverage in the soil (> 30 %) as well as the water and wind erosion were moderate in both treatments. The treatment (Cs/i) qualified as moderate, with a value of the quality index of 28 and (C/i) qualified as Good, with a value of the quality index of 31.

The treatment where the permanent canavalia was maintained (C/p) showed more significant improvements, with a granular texture, without cracks; the structure and consistency of friable soil, without clods, with predominance of fine aggregates; with the presence of macropores and few micropores, with a better structure. The soil acquired a firmer and darker shade of color in relation to the rest of the treatments, being dark brown (10.0 YR 3/3); there were no mottles; the presence and number of earthworms increased. The effective depth of the roots was 0.60 cm. There was a good level of surface waterlogging; the superficial crusts were small or did not occur and the surface coverage was greater than 70 %.

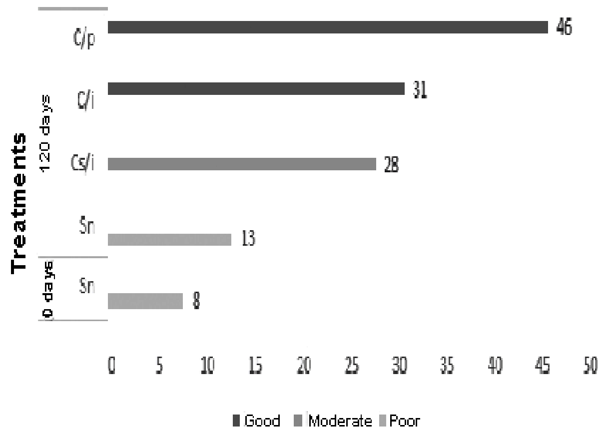
The indicators in the treatment improve the condition of the soil in relation to the rest, which is why it reached a quality index of 46 and was rated as Good.

The results obtained in the visual evaluation corroborated the evolution in the improvement of the physical properties of the soil when the canavalia was used. At the zero days, the values reached by the indicators did not exceed the maximum value of three, while seven showed values of zero; which shows loss in the main physical properties of the soil that attributed a condition of Poor. However, after 120 days, the values reached where the legume was kept managed to reach values of six and four, while only two showed values below three.

In general there was a correspondence between quantitative and qualitative properties proven in this work; especially for the variable porosity. Proving that these indicators are closely related to each other, for example an increase in the presence of macropores increases aeration regulates the movement of water and this favors the permeability and humidity in the soil that showed increases from 10.7 to 18.9 %. The increase in soil porosity from 53 to 57 % also affects the improvement of crust and surface coverage indicators, limiting soil compaction; hence, the bulk density decreased from 1.26 to 1.16 Mg m^{-3}.

If we analyze the qualitative evolution of the physical properties of the soil in the presence of *Canavalia ensiformis* (Figure 3), it is evident the effect of this legume in the increase of its quality, which behaved similarly as a poor soil at 0 and 120 days without the cultivation of green manure (Sn), but which became of a moderate quality when the crop was established (Cs/i), and which allowed it to become a good quality soil when incorporated (C/i) and by staying permanently on the ground (C/p).

There are several authors who confirm the role of legumes in the improvement of physical properties, for which the studies on this matter continue with important discretions; In this regard (20) they state that legumes, in addition to increasing organic matter, maintain soil moisture, reduce the temperature in the system, and also methanogenesis, among others.



Sn: Natural soil, Cs / i: Canavalia without incorporation, C / i: Canavalia incorporated, C / p: Canavalia permanent

Figure 3: Soil quality index

It is also suggested that effects associated with soil management such as the use of pesticides affect soil conditions, observed in the initial characteristics of this soil as a result of inadequate management. The use of *Canavalia ensiformis* allowed modifying the initial condition of the soil.

However, it is considered that the effects on the soil are diversified in rotation with cereals, since it allows improving the structure of the soil breaks the cycles of pests and diseases and reduces, consequently, the need for fertilizers and pesticides (21).

CONCLUSIONS

- The use of the *Canavalia ensiformis* legume as a green manure/cover crop showed a positive effect on the physical properties of the soil, an effect that was higher when the legume was incorporated into the soil after its cut at 80 days and when it remained in permanent form for 120 days.
- Favorable conditions were observed in the physical properties of the Differentiated Fluvisol soil, in a quantitative way (apparent density, porosity, humidity) as qualitatively (texture, structure, consistency, color, porosity, crust and surface cover, presence of earthworms, waterlogging and erosion) that corroborate a change in the quality of it.

♦ The visual quality index of the soil in the treatments tends to increase in relation to the control, with the use of *Canavalia ensiformis*, although numerically the changes are not significant.

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