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Performance of varieties of green manure in conventionally used soil

Amilcar Isidro Servín Niz*, Wilfrido Daniel Lugo Pereira, Derlys Fernando López Ávalos, Alexis Saúl Muñoz Pérez, Modesto Osmar Da Silva Oviedo and Eulalio Morel López

Universidad Nacional de Concepción (UNC), Concepción, Paraguay.

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The objective of this research was to evaluate the performance of different types of summer green manures in conventionally used soil. This research project was carried out in the district of Concepción (Paraguay). A Randomised Complete Block Design (RCBD) was used, consisting of four treatments and five repetitions. The treatments were *Mucuna pruriens* (T1); *Canavalia ensiformis* (T2); *Dolichos lablab* (T3) and *Cajanus cajan* (T4); each experimental unit had an area of 10 m^2. The measurements that were evaluated were the green mass of weeds at 60 and 90 DAE, and the production of green mass and dry mass by each of the evaluated varieties of green manure crops at 90 DAE. The results were analysed using the Tukey Test at the 5% level of probability. The results that were obtained show that there were differences in the production of green mass: the biggest production was shown by T2 with 27.6 mg ha^{-1}. The biggest producer of dry mass was T4 with 7.06 mg ha^{-1}.

Key words: *Cajanus cajan, Canavalia ensiformis, Dolichos lablab, Mucuna pruriens.*

INTRODUCTION

The use of leguminous species as green manure for the improvement of soil through the incorporation of large quantities of organic material, whether in the form of green matter or crop stubble, is a common practice and recommended for the improvement and maintenance of the organic material content and productivity of soils in almost all of the world's production regions.

Green manures are cultivated plants that provide benefits to the soil, generally during the flowering period, with the aim of achieving agronomic improvement. They are grown between rows of crops in fruit plantations or between two main crops that are temporally separate in rotation. At times, the green manure is a companion plant during part of the cycle of the main crop (Guzmán and Alonso, 2008).

Soil degradation understood as human-caused processes that reduce current and/or future capacity of the soii, is related to climate, the intrinsic characteristics of the soil, and above all, to deforestation (Ramírez et al., 2011). Its main effect is the modification of the micro ecosystem within which life develops in the soil. Additionally, bad practices for working the soil should be mentioned, as they do not favour the improvement of the physical, chemical and biological properties of soil.

For this reason, green manures can be used as part of the rotation system or as companion plants to crops to

*Corresponding author. E-mail: servinamilcar@gmail.com.

facilitate the task of soil recovery by small-scale farmers. The use of green manures seeks to improve the physical, chemical and biological properties of the soil; techniques that cause deleterious effects on life forms within the soil are not employed. The present research project displays the importance of the use of summer green manures for the production of organic material.

The use of organics plays a major role in maintaining soil health due to buildup of soil organic matter; beneficial microbes. To sustain the soil fertility and crop productivity, the role of organic manures and fermented organic nutrients are very important. The organic fertilizers in addition to nutrients contain microbial load and growth promoting substances which helps in improving the plant growth, metabolic activity and resistance to pest and diseases. Boosting yield, reducing production cost and improving soil health are three inter-linked components of the sustainable triangle. Therefore, suitable combination of chemical fertilizer and organic manures cultures need to be developed for particular cropping system and soil. The organic products besides supplying nutrients to the first crop, also provides substantial residual effect of unutilized nutrients on the succeeding crop (Lalith et al., 2013).

The microorganisms benefited from the presence of diversified organic residues in the soil, due to the utilization of the substrate for increased microbial biomass. Studies has indicated a reduction of the biodiversity of the ecological relations in the soil (Medeiros and Lopes, 2006; Muñoz et al., 2017; Ascari et al., 2018). So too, soil covered with plants is an effective way to suppress weed growth and reduce soil erosion and nutrient leaching while increasing soil organic matter and sustaining long-term soil fertility and crop production (Fageria et al., 2005; Montemurro et al., 2013).

Following on from the points discussed above, the objective of this research was to evaluate the performance of different types of green manures on conventionally used soil.

MATERIALS AND METHODS

The experiment was carried out in the District of Concepción (Paraguay) at geographical coordinates 23º 20' 35.5' latitude south and 57º 11' 47.7' longitude west, 200 m above sea level. The soil of the region is characterized by a fine and weakly structured loamy sandy texture (López et al., 1995). To determine the chemical characteristics of the soil, 40 sub-samples of the litter from 0 to 0.20 m depth were collected in various parts of the experiment area with the following results, pH $CaCl_2$ = 5.56; P = 6.31 mg dm^{-3}; K = 0.24 $cmol_c$ dm^{-3}; Ca = 2.88 $cmol_c$ dm^{-3}; Mg = 0.41 $cmol_c$ dm^{-3}; Al = 0.00 $cmol_c$ dm^{-3}; H+Al = 2.21 $cmol_c$ dm^{-3}; CIC = 5.75 $cmol_c$ dm^{-3};V = 61.52 % e MO = 1.01%. The region has a climate that is transitional between a Mediterranean type climate and a humid climate with mean annual temperature of 24°C and mean annual rainfall of 1000 to 1200 mm. The months of most rainfall are December and January, and those of least rainfall are June, July and August (DINAC, 2016). A Randomised Complete Block Design (RCBD) was used, with 4 treatments and 5 repetitions. The treatments consisted of 4 green manure crops of the fabaceae family: T1, *M. pruriens*; T2, *C. ensiformis*; T3, *D. lablad* and T4, *C. cajan*. The experimental units consisted of plots measuring 100 m in which the treatments were implanted. There was a 2 m walkway between the experimental units. The *M. pruriens* and *D. lablad* had a density of 0.50 m between plants and 1 m between rows, holding approximately 40,000 Pl/ha^{-1}. The *C. ensiformis* had a density of 0.30 m between plants and 0.50 m between rows, containing around 66, 600 Pl ha^{-1}. The *C. cajan* had a density of 0.50 m between rows and 18 plants per metre, with approximately 140.000 Pl ha^{-1}. The measurement of each experimental unit was done with a 50-m measuring tape. The total measurements of the sides were of a width of 50 mand a length of 62 mm (50 x 62), representing a total area of 3100 m^2. In accordance with the experimental design, the distribution of each treatment within the experimental area was done at random. The areas that were to be used for the cultivation of the green manures were then cleared. This clearing consisted of one passing-over with a brush cutter; the plant debris was left as a coverage on the ground. Soil samples were then taken in order to ascertain the current state of the soil. The methodology consisted of taking a sample of 30-cm depth from each experimental unit using a spade. The samples were subsequently packaged and sent to a laboratory. After the preparation of the experimental units and the taking of soil samples, the planting of the different crops was carried out. This was done with a manual seed drill; 2 to 3 seeds were deposited in each hole in accordance with the parameters established for each species. During the growth and development of the crops that were used as green manure, relevant measures of care were taken as needed. Just one weeding was carried out 8 days after the emergence of the seedlings using a hoe. In regards to the availability of water, this was provided by rainfall during the crop cycle. The materials used for the collection of data were: pens, markers, a notebook, plastic bags, a bucket, bags, machetes, spades, hoes and scales. In order to determine the increase in growth (%), the height of the plants was evaluated at 30, 60 and 90 DAE (days after emergence). Six plants were evaluated per experimental unit using a tape measure showing centimetres, using the equation:

$$\text{Increase in growth (\%)} = \frac{initial\ height}{final\ height} x100$$

In order to determine the green mass of weeds, a 1 m^2 wooden frame was used at 60 and 90 DAE to determine the area in which measurements were to be taken. Subsequently, machetes were used to cut the weeds at ground level within the selected area. Then, the weeds from each experimental unit were gathered in bags so that they could later be weighed. To determine the production of green mass and dry mass, a 2 m^2 area was measured in each experimental unit by throwing the 1 m^2 wooden frame at random two times. Machetes were used to cut the plants found within the area and these plants were then collected in bags to be weighed using the scales. The results were extrapolated for one hectare. The green mass that was gathered was dried by placing it in the sun on tarpaulins for 15 days until a constant weight was achieved. All measurements were carried out following the procedures described by (Berlingeri, 2008). The values that were obtained for each treatment were submitted to an analysis of variance ANOVA. For each of the measurements carried out, and where significant effects were observed, comparisons were made using the Tukey Test at the 5% level of probability.

RESULTS AND DISCUSSION

Increase in growth

In Table 1, the percentage increase of height between

Table 1. Comparison of averages of the percentage growth increase of *Mucuna pruriens, Canavalia ensiformis, Dolichos lablad* and *Cajanus cajan* at days after emergence (DAE).

Treatments	Growth increase (%)	
	30 to 60 DAE	**60 to 90 DAE**
Mucuna pruriens (T1)	30.6b	40.3a
Canavalia ensiformis (T2)	45.4b	18.1b
Dolichos lablad (T3)	70.6a	17.3b
Cajanus cajan (T4)	40.6b	33.3a
LSD	15.1	13.7
CV (%)	17.1	26.78
OA	46.82	27.2

Averages followed by the same letter are shown as different by the Tukey Test at the 5% level of probability. LSD, Least significant difference; CV, coefficient of variation; OA, overall average.

measuring periods can be observed. Highly significant differences are seen between the treatments. In the first period, T3 had the highest percentage of growth with an increase of 70.6%; this is statistically superior to the other In the second period, a high significant difference was observed. T1 and T4 are statistically equal; these two treatments showed the highest percentage of growth, with 40.3 and 33.3% respectively. T2 and T3 were equal. A minimal difference of 13.7%, a coefficient of variation of 26.78% and overall average of 27.2% were seen. It should be mentioned that the height obtained by each of the species that were studied varied during the two measurement periods as some species have different growth habits. The legume that showed least height increase during the second period was the *D. lablad* (17.3%). This is because at 70 DAE, it began to develop flowers, practically paralysing vegetative growth. Furthermore, it was seen to be affected by the intense cold and frosts. It was observed to be more sensitive than the *M. pruriens*, many of the plants were partially burnt, which led to them not reaching a suitable size. Carballo (2000) describes *C. cajan* reaching a height of 145 cm at 80 DAE, which is superior to that which was obtained in the present study: an average height of 119.5 cm was recorded at 90 DAE. This is because this study was carried out under different climatic conditions, which included adverse climatic conditions that directly intervened in the vegetative development of the plants. García (2002), in a study of the cycle and the biomass productivity of species of creeping and semi-creeping legumes (*D. lablad, Canavalia ensiformis* and *M. pruriens*) in sandy soils, found that *M. pruriens* had a length of 110.5 cm at 60 DAE and 190 cm at 100 DAE, a height increase of 42%. This coincides with this study: the *M. pruriens* showed higher growth than the other treatments in the second period of evaluation from 60 to 90 DAE, obtaining a percentage of growth of 40.3%. Considering that in this study climatic conditions were unfavourable in the first period of evaluation, abundant growth of the *M. pruriens* was not seen; according to treatments. T1, T2 and T4 are statistically equal. A minimum significant difference of 15.1%, a variation coefficient of 17.1% and an overall average of 46.82% were recorded for the first evaluation period. García (2002), it is considered the most aggressive of the species that were evaluated.

Green mass of weeds

Table 2 shows the green mass of weeds in the different treatments. It can be seen that at 60 DAE, there were no significant differences between the treatments. All the treatments were statistically equal, but it can be appreciated that T1 has less green mass with 3.1 mg ha^{-1}. The overall average was 4.5 mg ha^{-1}; the least significant difference was 2.6 mg ha^{-1} and there is a coefficient of variation of 30.52%. It can be observed that at 90 DAE, there are highly significant differences between the treatments, with the lowest incidence of weeds in T4 with 1.4 mg ha^{-1}. The other treatments T1, T2 and T3 were statistically equal, with a least significant difference of 1.2 mg ha^{-1}, and a coefficient of variation of 28.24%. In Table 3, the percentage decrease of weeds (green mass) can be seen from 60 to 90 DAE in the different treatments. T4 shows the largest decrease (70.8%), followed by T2 with a percentage decrease of 57.8%.

Uribe et al. (2000) considered that treatments with legumes produce positive effects for the reduction of aerial biomass of weeds. Working with *C. ensiformis* and *M. pruriens,* they achieved a low level of production of weed biomass; these crops were efficient at decreasing the proliferation of weeds, suppressing 52% of the weeds from 80 to 110 DAE. This shows that they can be used as a biological method to control weeds. In correlation with the present study, the *C. ensiformis* from 60 to 90 DAE is better than the *M. pruriens* in regards to the reduction of weed green mass, which is reduced by 57.8%. This is due to the density that was employed, as it produced a

Table 2. Comparison of averages for the measurement of foliage of weeds of *Mucuna pruriens, Canavalia ensiformis, Dolichos lablad* and *Cajanus cajan* at days after emergence (DAE).

Treatment	Green mass of weeds (Mg ha^{-1})		Reduction of weeds (%)
	60 DAE (ns)	90 DAE (**)	60 to 90 DAE (**)
Mucuna pruriens (T1)	3.1	2.5 b	19.4c
Canavalia ensiformis (T2)	4.5	1.9ab	57.8ab
Dolichos lablad (T3)	5.6	2.9b	48.2b
Cajanus cajan (T4)	4.8	1.4a	70.8a
LSD	2.6	1.2	18.4
CV (%)	30.52	28.24	20.32
MG	4.5	2.2	48.2

Averages followed by the same letter are shown as different by the Tukey Test at the 5% level of probability. LSD, Least significant difference; CV, coefficient of variation; OA, overall average.

Table 3. Comparison of averages for the measurement of green mass and dry mass of *Mucuna pruriens, Canavalia ensiformis, Dolichos lablad* and *Cajanus cajan* at days after emergence (DAE).

Treatments	Green mass (**)	Dry mass (**)	Percentage of DM (**)
	mg ha^{-1}		
Mucuna pruriens (T1)	19.9b	4.02b	20.2b
Canavalia ensiformis (T2)	27.6a	6.60a	23.9b
Dolichos lablad (T3)	17.6b	4.3b	24.4b
Cajanus cajan (T4)	19.5b	7.06a	36.2a
LSD	5.5	1.8	7.8
CV (%)	13.93	17.87	15.5
MG	20.9	5.5	26.9

Averages followed by the same letter are shown as different by the Tukey Test at the 5% level of probability. LSD, Least significant difference; CV, coefficient of variation; OA, overall average.

quicker covering of the soil, which caused competition between weeds and consequent reduction. It can be seen that at 90 DAE, treatments T1, T2 and T3 are statistically equal, however, only T1 and T3 are superior to T4. Sanclemente (2009) evaluated some benefits of the use of coverings of *M. pruriens* and *C. ensiformis* for a maize crop. Results showed that there was a 74.4 and 72.9% maximum suppression of the amount of weeds for the treatments with *M. pruriens* and *C. ensiformis* respectively. The species of weeds that were most reduced by the coverings were *Cynodon dactylon* and *Brachiaria*. The most dominant species during the experiment was *Cyperus rotundum*. In comparison, during the present study with *M. pruriens* and *C. ensiformis*, a weed reduction of 19.4 to 57.8% was achieved at 60 to 90 DAE due to the aggressiveness of these weeds and to the fact that weeding was only carried out at 10 DAE. However, in this study the green mass of weed species was also reduced; *C. dactylon* and *C. rotundum* were the predominant species in the experimental area. Similarly, Rubio, using *C. ensiformis*, *M. pruriens* and *D. lablad* for an investigation on weed control, states that on comparing populations of *C. rotundum* at the end of the study, significant differences between the treatments were not found. All of the treatments had reduced the population by 85% at 109 days after sowing. In the present study, there were significant differences at 90 DAE between the different species of green manures for the reduction of weed populations; the results are not uniform due to the crop density that was employed and to the fact that development of the different crops was not uniform. Studies carried out by Sevilla (2008) indicate that at 30 and 45 days, there was no decrease in grass, broadleaf and *Cyperus* populations. This is because the coverings did not provide uniform cover, therefore, relevant data on the reduction of weed populations was not found. However, Moreira et al. (2013) was able to observe differences in weed populations at 90 days, when the crops cover the entire cultivated area. The present study's results coincide with this: at 60 DAE the treatments were equal, but at 90 DAE reduction and differences in the amount of weed green mass could be observed in the different treatments. This is due to the cultivated area being completely covered by the green manures.

Green mass and dry mass of green manures

In Table 3, the production of foliage and dry mass of each treatment can be observed. There are highly significant differences between the treatments both in respect to production of green mass and dry mass. It can be seen that the biggest production of green mass was obtained by T2 with 27.6 mg ha^{-1}. Treatments T1, T2 and T4 were statistically equal. There are highly significant differences between the treatments in respect to the production of dry mass. T2 and T4 were statistically equal and T4 was higher than the other treatments with a production of 7.06 mg ha^{-1}. T1 had the lowest production of dry mass with only 4.02 mg ha^{-1}.

According to Jiménez et al. (2005), sowing density does not influence the production of dry biomass of *C. cajan*, and results achieved indicate that factors like the physical-chemical properties of the soil, the genetics of the plants and the management of the crop, amongst other factors, determine the level of production. A production of 7.65 mg ha^{-1} of dry mass of *C. cajan* was observed; a density of 172,000 plants hectare was used. In comparison, in the present study, a production of dry material of 7.06 mg ha^{-1} was seen. A density of approximately 66,600 planta hectare was employed, which is lower than the density used by Jiménez et al. (2005). As a result, it is shown that population density does not influence the production of green mass and dry mass in the cultivation of *C. cajan*, and that, as mentioned, other factors are responsible. The broad adaptability of *C. ensiformis* and *M. pruriens* to diverse climatic conditions allowed good development during the cycle. The samples that were taken indicated that the *C. ensiformis* produced 10.8 Mg ha of dry biomass whilst the *M. pruriens* produced 7.5 mg ha^{-1} (Barreto et al., 2002). Equally, in the present study, the *C. ensiformis* showed abundant growth in the first period (Table 2) in spite of climatic conditions during the cycle. A production of 27.6 mg ha^{-1} foliage was seen, which was more than the other species. However, it had a dry mass production of 6.6 Mg ha^{-1}. This was less than the *C. cajan*, which had the highest production of dry mass at 7.06 Mg ha^{-1}: this dry mass represents 36.2% of the green mass that was recorded. In comparison, the *M. pruriens* had a green mass production of 19.9 Mg ha^{-1} and a dry mass production of 4.02 mg ha^{-1}, which is equivalent to 21.4%; this is less than the *C. cajan*. This difference is due to the fact that *C. cajan* has woodier stalks and a lower water content. Rubio (2006) indicates in a study that *C. ensiformis* was the crop that produced most dry mass: it produced 5.5 mg ha^{-1} of dry mass and 30 Mg ha^{-1} of green mass. This is reflected in the closure speed of the crop, which was 70-80 days after sowing. In comparison, *D. lablad* and *M. pruriens* are more aggressive crops, which start to close at 40-50 days after sowing and close entirely at 60-70 days. In the present study, the *C. ensiformis* is g ha^{-1} respectively; these results are higher than those obtained by Rubio (2006). This is due to the fact that *C. ensiformis* displayed higher height increase during the first period. This height increase was larger than that of the other species of green manures, due to the fact that the *M. pruriens*, *D. lablad* and *C. cajan* were affected by the weather.

The longer legumes are left growing, the larger the amount of dry mass accumulated (Moreira et al., 2013). This can be observed within the present evaluation, which only lasted until 90 days after emergence due to the fact that the species began to enter their flowering stage; a larger accumulation of dry mass could be obtained from all the species. Ferreira et al. (2016) recorded a result regarding the production of dry mass at 120 DAE: 9.57 mg ha^{-1} for *C. ensiformis*, 10.28 mg ha^{-1} for *M. pruriens* and production of 10.12 mg ha^{-1} for *C. cajan*. These results are higher than those gathered in the present study, which lasted 90 days; above affirmation made by Moreira et al. (2013) which can be seen as the cause of this difference. Martin (2009) obtained a dry mass production of 9.76 mg ha^{-1} for *C. ensiformis*, confirming that the plant grows well during periods of rain and long days, which confirms it to be a good green manure. This is also shown in the present study, in which good rainfall was had during the cycles of the different species; *C. ensiformis* responded well to these conditions in spite of the very low temperatures and short days. *C. cajan* also obtained a good dry mass production of 7.06 mg ha^{-1}

Conclusions

In comparison with *C. ensiformis*, the use of *M. pruriens, D. lablad*, and *C. cajan* favours the production of vegetable coverage to a lesser extent. *C. ensiformis* showed the best coverage, giving constant coverage throughout the year as a companion plant and/or within a crop rotation system.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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