Performance of the below ground root biomass in different grasslands of Mayabeque province, Cuba

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For studying the below ground root biomass performance in different grasslands of Mayabeque province, six dairy production units located in San José de las Lajas municipality were selected. They had different types of soils, grasslands and management systems. Samplings were carried out in both climatic periods and in each unit the most representative areas were chosen. Through a transept three soil samples were collected with 50 mm diameter cylinders, at two depths (0-5 and 5-10) to determine the below ground root biomass. In the studied profiles more than 80 % of the below ground root biomass is found in the soil layer 0-5 cm. There was no interaction between season and soil layer in the different daily units. Results obtained are great interest, since they evidence the potential contribution of organic matter to the soil. Also, from them the indices and diagnoses of soil resource can be predicted.

Key words: *below ground root biomass, grasslands, grasses*

Presently, the development and agricultural expansion policies have frequently led to land degradation. It is evident the decrease in productivity and the increase in production costs. Additionally, problems related to water supply, floods, landslides and sedimentation in water reservoirs are noticed. In fact this brings about important economical and social consequences (Pla 2009). Soils of cattle raising ecosystems are not excluded from this situation and show high degree of degradation and deterioration. In these ecosystems, the below ground root biomass can exceed 80% of the total of the plant and can counteract these effects, besides being an indicator of great usefulness to understand soil functioning. In turn, the biomass serves as support to the microbiological complex and to the micro and macrofauna of the edaphic community.

Researches on radicular biomass and other below ground components have reached poorer development in the tropics than in temperate countries (Perez-Quezada *et al*. 2011). In tropical savannas, Lamotte (1975) realized different studies in Ivory Coast and Africa. In Cuba, Fiala and Herrera (1988) and García *et al*. (1990) studied the aerial and below ground root biomass in savannas and in different agricultural ecosystems of grasslands, the same as Hernández and Armas (1993), Pérez *et al*. (1996) and Hernández and Rodríguez (2001).

The objective of this paper was to characterize the root biomass and other below ground root components of different cattle raising ecosystems of Mayabeque province, for determining their contribution to the general fertility of the soil.

Materials and Methods

The study was conducted during the two seasonal periods (rainy (May-October) and dry (November-April) of 2004, in six dairy units of Mayabeque province. Table 1 shows the general characterization of the studied grasslands, regarding their area, number of paddocks, type of relief, stocking rate, predominating pasture species and type of soil.

Soil classification was realized according to Hernández *et al*. (2006) and the World Reference Base (WRB) (IUSS Working Group WRB 2008). Annual mean of rainfall was of approximately 1200-1600 mm (80 % in the rainy period). Annual mean temperature registered values between 24.8 and 25.2 ºC.

In each unit the most representative areas of the predominating grassland condition were selected. In the case of the units with existence of biomass banks of *Pennisetum purpureum* cv. Cuba CT-115 (units 1, 5 and 6), the study was only developed in the area of unit 6. This was represented as unit 6a, since in the rest the grassland management did not correspond with the technology proposed by Martínez and Herrera (2006).

In this case, in 70% of unit 6, was only shown during the rainy period (RP), due to damages in the experimental area. The sampling to determine the below ground biomass was randomly made through a transept, three soil samples were taken in each plot with 50 mm diameter cylinders (15 samples) at two depths (0-5 and 5-10 cm). The study included living and dead components.

All the material was washed in bag, with 0-1 mm mesh flow and plenty of water. In the samples of 0-5 and 5-10 cm the living and dead components were determined through tinting with red Congo at 1 % (Ward *et al*. 1978 and Tesarova *et al*. 1982). The material was

Table 1. Characteristics of the units and of the soils studied

Unit	Characteristics	Pasture species	Type of soil
1	49 ha divided into 76 paddocks Flat fields. Stocking rate: 1.97 LAU/ha Proportion 50-50 % natural and improved pastures	*Leucaena leucocephala*/ *P. notatum* y *D. anulatum* *Pennisetum purpureum* vc. Cuba CT-115 *C. nlemfuensis* *P. notatum* y *D. anulatum*	Yellowish ferrallitic (Alfisols)
2	62 ha, 78 paddocks of 0.38 ha and between 5 and 10 % slopes. Stocking rate 2.27 LAU/ha. Natural pasture + silvopastoral leucaena system	*Leucaena leucocephala*/ *P. notatum* y *D. anulatum*	Brown with carbonate (Inceptisol)
3	83 ha, 30 paddocks of 0.80 ha and lands with slight slopes. Stocking rate: 1.22 LAU/ha. More than 50 % of natural pasture	*Sporobolus indicus* *Paspalum virgatum* *C. nlemfuensis*	Brown with carbonate (Inceptisol)
4	80 ha of lands with slopes between 10 and 15 %. 40 paddocks of 1 or 2 ha. Stocking rate: 1.63 LAU/ha. More than 50 % of natural pasture	*Paspalum notatum* *Dichantium anulatum* *Cynodon.nlemfuensis*	Brown with carbonate (Inceptisol)
5	42 ha divided into 54 paddocks. Flat lands. Stocking rate: 2.27 LAU/ha. More than 50% of improved pastures	*S. indicus*, *P. notatum* *C. nlemfuensis* *Pennisetum purpureum* cv. Cuba CT-115	Red ferrallitic (Oxisol)
6	60 ha divided into 100 paddocks of 0.65 ha Flat fields. Stocking rate: 1.8 LCU/ha. Proportion 50 % natural pasture 50 % improved pasture	*P. notatum* and *D. anulatum* *C. nlemfuensis* *Leucaena leucocephala*/ *C. nlemfuensis* *Pennisetum purpureum* cv. Cuba CT-115	Hydromorphic (Entisols) and Red ferrallitic (Oxisol)

divided into roots, rhizomes and detritus (living and dead). After washed and separated, the material was put in an oven at 70º C for more than 24 h and weighed in a precision balance.

Root biomass production and disappearance of the below ground components was estimated through the increase and decrease noticed between the rainy and dry seasons, according to the method proposed by Sims and Singh (1978). The analysis of the rate of root biomass increase and disappearance was estimated by the formulas of Pérez and Smid (1984) and according to the methods referred by Kvet *et al*. (1971). The formula was the following:

$$C= \frac{W_2 - W_1}{P(t_2 - t_1)} = g.m^{-2}.a^{-1}$$

Where:
W_1 = Biomass at an initial time
W_2 = Biomass at a final time
P = m^2
t_1= Initial time
t_2 = Final time
C = Increase or decrease

The renewal rate was calculated by Singh and Singh (1981) by the formula:

$$RR = \frac{X\ max - X\ min}{X}$$

Where:
X max: maximum biomass (g)
X min: minimum biomass (g)
X: average biomass (g)
RR: Renewal rate

Results were processed according to a linear model, where the effects of season and the depths studied were considered for each unit characterized.

Results and Discussion

The aerial and radical biomass of the plants, besides fulfilling certain specific activities, adds great amounts of organic matter to the soil. Root functions are related to the integrating tissues, the size and its morphological characteristics. The support, nutrient conduction and the greatest part of carbon fixation below the soil is in charge of the roots which present mainly secondary tissue. Nutrient and water absorption are related to the roots showing primary tissue. These latter are commonly denominated thin roots and are characterized by being one the most dynamic and active structures of the plant (Jiménez and Arias 2004).

The statistical analysis did not show interaction for the evaluated effects (season and depth) in any of the units studied. Grassland conditions were very variable, regarding the predominating type of pasture, the existence of creeping or erect pastures and the type of soil. This could be related to the differentiated performance between each one of the units studied. In this sense, in international literature different authors attribute the differences in the radicular development of pastures to the genetic characteristics of each species (Yates and Jacques 1988 and Pengelly and Hacker 1998), to the plant age (Gómez-Carabalí *et al*. 2010), to the climate (Kirk *et al*. 1989) and to the physical properties of the soil, especially its texture and structure (Fiala *et al*. 1991, Hernández y Fiala 1992 and Vilche *et al*. 2000).

February and Higgins (2010), in studies realized with isotopes (^{13}C and ^{15}N) in grassland systems with tree species and grasses, demonstrated that root distribution is directly related to the content and N distribution in the soil and is inversely proportional to the humidity.

Figure 1 represents the total below ground root biomass performance in both climatic seasons. In the 0-10 cm soil layer, values range between 571 and 3929 g.m^{-2}. In units 1 and 5 there were no significant differences between seasons, while in the remaining units there were certainly differences ($P < 0.01$ and $P < 0.001$).

According to Walter *et al*. (2012), the climatic factors and especially, the variability of the volume, frequency and rainfall distribution, followed by long drought periods, can reduce the net productivity of the radicular systems until 15% in grasslands of temperate climate.

Studies of Martuscello *et al*. (2009) demonstrate that there are other factors directly influencing on the radicular systems of pastures, for example the shade level. These authors determined reduction of root production from 45 to 65 %, when they were cultivated with 50 % shade and from 73 to 93 % when the shade increased to 70 %. However, Carrilho *et al*. (2012) in species of the same genus revealed that some shade levels (50 and 30 %) stimulated the radicular growth (7.31 and 4.59 g/plant), unlike what it occurred with the plants which were in the sun (2.80 g/plant). Therefore, further research on this topic and the adequate characterization of the different agricultural ecosystems are necessary.

Perennial grasses for grazing differ, to a great extent, in volume and the biomass of their radicular systems. Lower values (345 – 230 g.m^{-2}

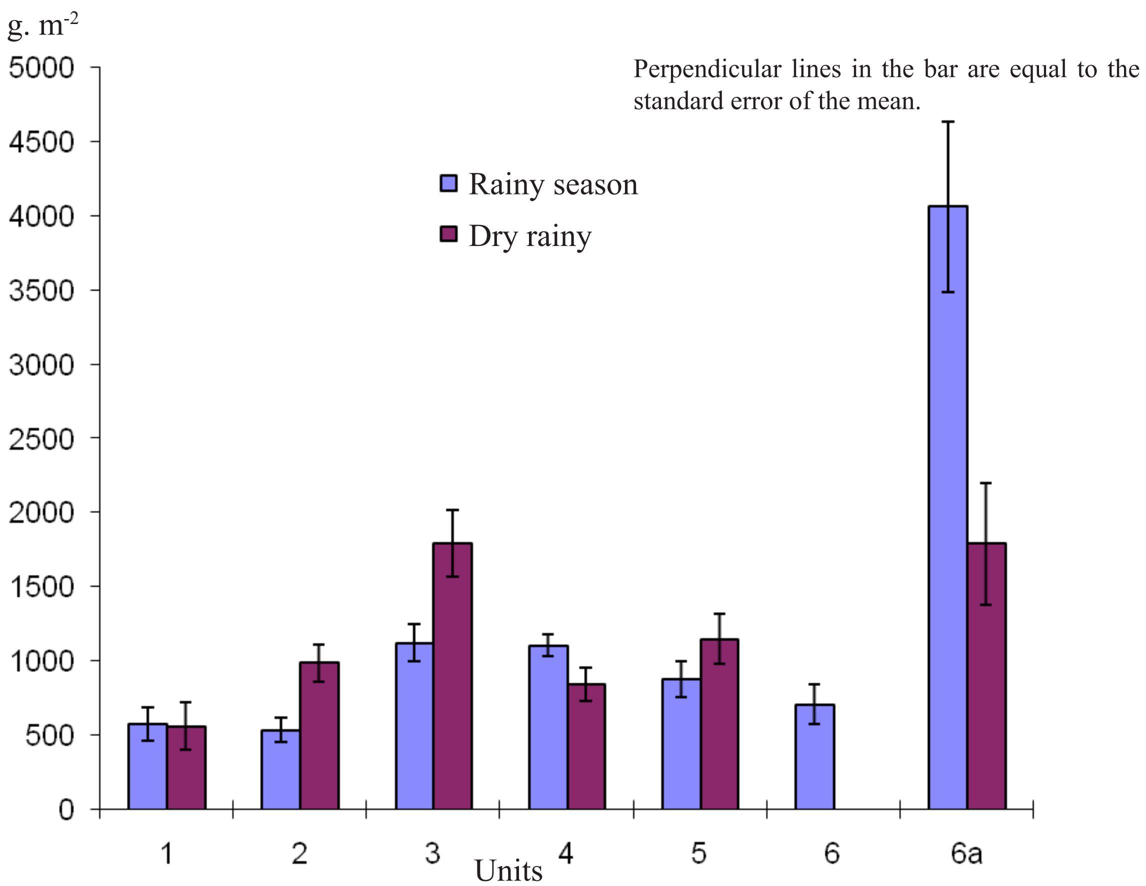

Figure 1. Below ground root biomass in the rainy and dry seasons in different grasslands of Mayabeque province, Cuba

are shown in the savannas of Venezuela (Medina 1982) and the South of Africa (Huntley and Morris 1982 and Medina 1982) and the highest (1900 – 1050 g/m^2) in the savannas of the South of Africa (Meneaut and César 1979 and 1982). In Cuba, Yepes and Alfonso (1972) reported an average values of radicular biomass of 667 g.m^{-2} in six pasture species. However, Hernández *et al*. (1998) indicated a marked variation in the biomass values of a *Cynodon nlemfuensis* grassland (564 to 1334 g.m^{-2}). More recently, Crespo and Lazo (2001) determined similar values (1000 g.m^{-2}) for this same species and higher (1131.85 g.m^{-2}) for *Panicum maximum*.

Hernández and Rodríguez (2001) observed that in grasslands where the traditional grazing system is applied, results behave similarly. In the rainy period greater root biomass can be observed. However, in Voisin's rational grazing system, where the stocking rate is higher, the result is different. This indicates the influence of the type of grazing in the root biomass performance. Eekeren *et al*. (2010) demonstrated the advantages of the utilization of grass and legume systems, regarding the N contribution of the below ground biomass and the relationship mineralization and OM accumulation in the soils.

According to Hernández and Sandrino (2002), the percentages of the living root biomass components are higher in the rainy period. These authors consider that the aerial components increase with the vegetative period, and those below ground decrease due to nutrient translocation to the aerial part. Also, the dead components are reduced due to the increase of the activity of the edaphic biota, on improving the soil humidity conditions.

The percentages of living root biomass of the plant (aerial and below ground) ranged between 25 and 80 % for the dry period and between 22 and 70 % for the rainy. These values were higher than those reported (22.8 – 43.1 %) by Hernández (2002) in different grasslands at the Southwestern region of Sierra del Rosario, Cuba.

In the grasslands studied, the percentage of below ground components (figure 2) is different. Roots vary between 24.8 and 35.3 %, rhizomes between 16.8 and 43.9 % and detritus between 18.4 and 58.4 %. This indicates that the greatest variations are produced in the detritus and the lowest in the roots.

Generally, more than 80 % of the below ground root biomass is present in the 0-5 cm soil layer (figure 2) similar to Hernández *et al*. (1998) and Hernández (1999) that informed that this represents 65 % of the total profile.

Kellman and Sanmugadas (1985) in Belice, Central America, found at 60 cm depth soil profiles, similar values to those reported in this study, where at the 0-5 cm layer was found 62.9 %, whereas at 0-10 cm was established 84 % of the radical root biomass. Voisin (1962) stated that root accumulation at the upper (0-5 cm) layer was higher when rotation or the number of cuts in the pastures was increased. These aspects were also confirmed by Rodríguez *et al*. (1995 and 1996).

Studies carried out by López-Carrasco *et al*. (2011) demonstrated that total below ground root biomass did not differ substantially between grassland areas at grazing or not, although they confirmed that there is indeed a change in its vertical distribution pattern. According to these authors in grazed zones the highest part of the biomass is present at the first soil centimeters, with a remarkable amount at the soil layer classified as humus.

These results demonstrate that in grasslands and savannas, the 0-5 cm soil layer is fundamental for the functioning of the ecosystem, concentrating total rhizomes, high root proportion and greater detritus quantity. The percentage of living roots (figures 3) in the soil layers of 0-5 and 10-15 cm increased, in general, in the rainy season in most of the units. In

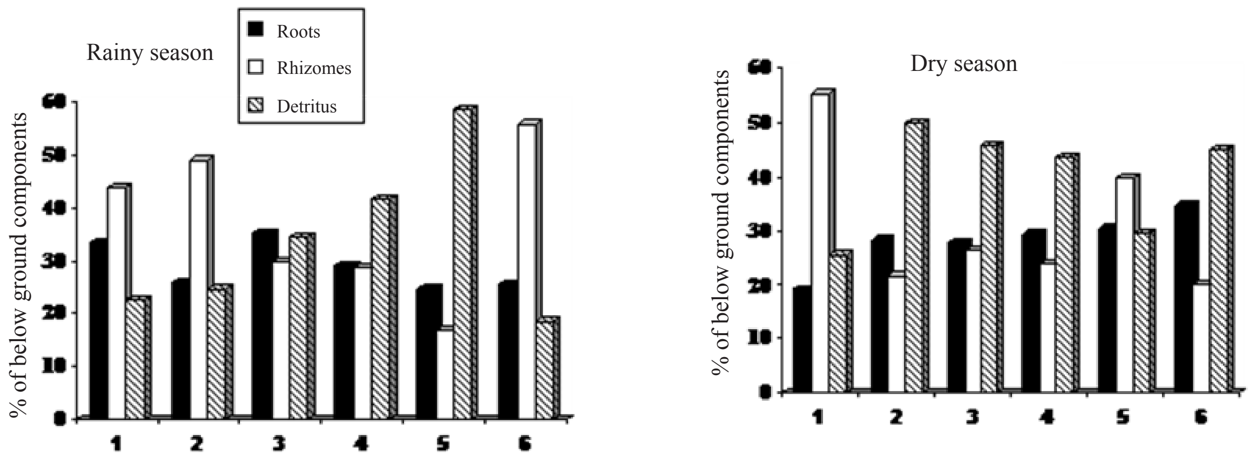

Figure 2. Percentage of below ground components at the 0-10 cm soil layer

both soil layers, the performance of unit 1 was more favorable in the dry season. This could be related with the predominance of Paspalum notatum in this unit and the high amount of non-structural carbohydrates (12 %) present in the roots and crown of this species (Adjei *et al*. 1988).

The average root increase in the grasslands with creeping species was of 101 g.m^{-2}, including the grassland of unit 6a that reaches 219 g.m^{-2}. These results agree with what was obtained with the species *P. purpureum* cv. Cuba CT-115. Clavero and Urdaneta (1997) described the morphology, development and function of the radicular system of dwarf elephant grass (*Pennisetum purpureum* cv. Mott) during the establishment stage. These authors determined that this species has good development of the radicular system with 75 % of the roots at the first 30 cm depth, and with absorbent roots at lower to 60 cm depths. They also reported a lateral growth taking mainly place at the 25 cm close to the center of the cluster. Therefore, the good capacity of soil exploration of the species of this genus, specifically for obtaining water and nutrients, is confirmed.

The renewal rate (RR) of the roots varied with the soil depth and was variable in the units attributed, maybe, to the different species present in each unit (figure 4).

It is concluded that the grasslands studied have certain stability in the radicular zone, since the variations produced in the renewal of the below ground components for the different climatic seasons allow the nutritional maintenance of the plants. At the 0-5 cm soil layer was found the highest amount of below ground root biomass, as well as the highest root proportion. This determines that at this layer high growth and renewal are produced. Grasslands of units 1 and 6a in the rainy season had the highest values of aerial root and thick root biomass. However, according to the percentage of living rhizomes in the rainy and poor rainy seasons seems to be the most stressed.

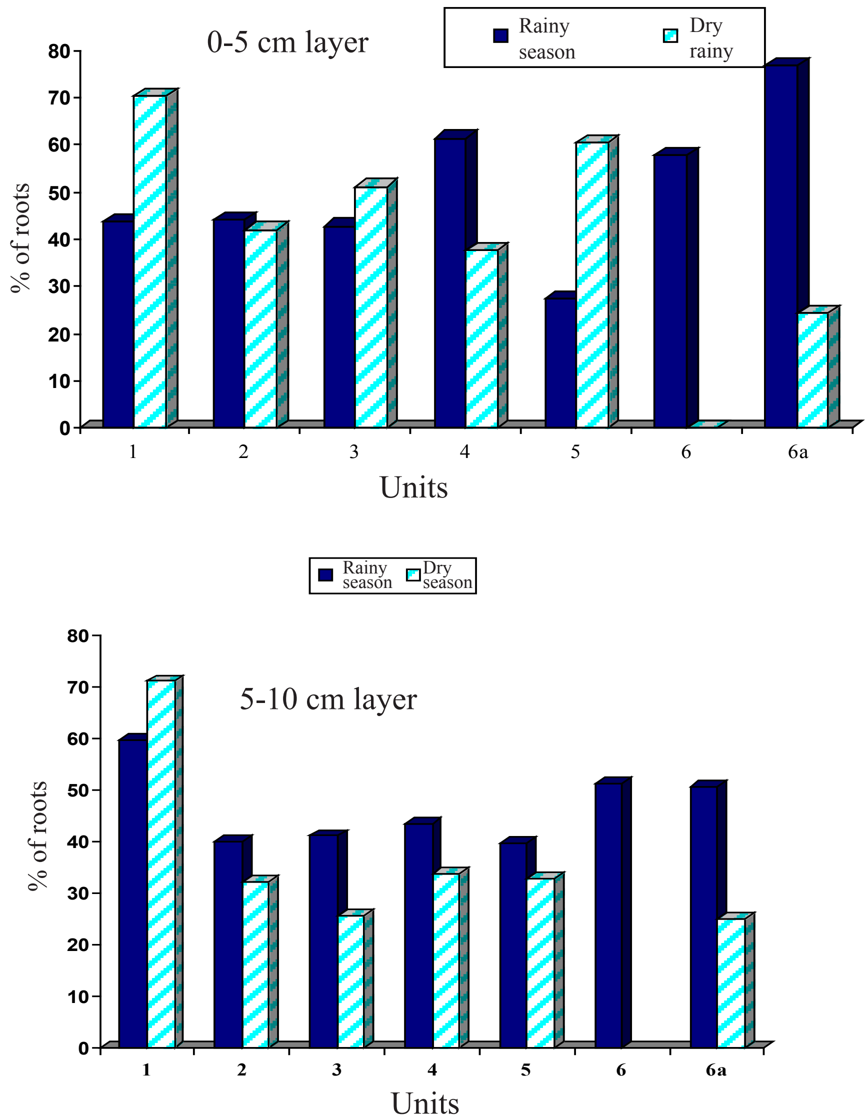

Figure 3. Percentage of living roots according to soil layers

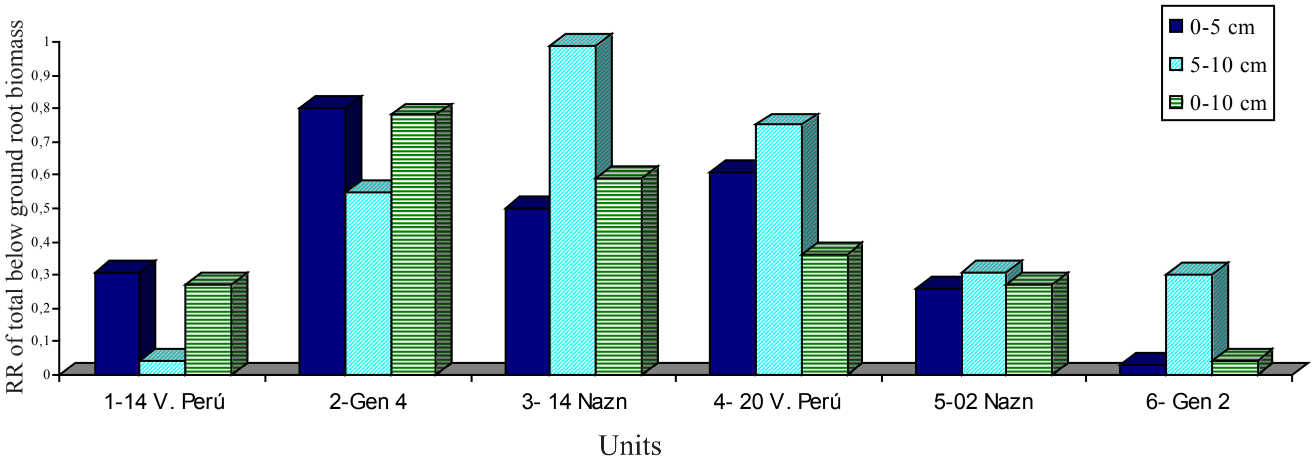

Figure 4. Renewal rate of the total below ground root biomass according to depths

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