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Growth Dynamic of Sugarcane Cultivars C97-366 and C99-374 for Forage Production

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Abstract

Context: Plant growth analysis is a valuable tool to detect biomass formation and accumulation. The determination of growth indexes enables plants to adapt to different edaphoclimatic conditions, and to select the most promising responses among them.
Aim: To characterize the growth dynamic of sugarcane cultivars C97-366 and C99-374, with forage purposes.
Methods: A randomized experimental block design with three replicas was used. The following growth indicators were evaluated: foliage surface, foliage surface index, crop growth rate, and net monthly assimilation rate, at 181 days (February) and 342 days (July), after planting. Correlation analyses were made to determine the best model fit for every indicator evaluated in the two cultivars, as well as the analysis of variance of regressions.
Results: Cultivar C97-366 was fit to a linear model for the foliage surface index, crop growth rate, and net assimilation rate; the foliage surface was fit to a polynomial model. Cultivar C99-374 was fit to a polynomial model for the foliage surface index, crop growth rate, and net assimilation rate; the foliage surface index was fit to a linear model.
Conclusions: Cultivars C97-366 and C99-374 showed genetic and morphological characteristics that lead to efficient physiological processes that determine proper biomass production.

Keywords: *Foliage surface, foliage surface index, net assimilation rate, crop growth rate.*

Introduction

Plant growth analysis is a valuable tool to know biomass formation and accumulation (Wilson García et al., 2017). Due to the large number of variables used to explain plant growth and development, the time used for its determination and variable instability resulting from different environmental and management factors that facilitates the interpretation of results and the general work, different indexes have been established (Fortes et al., 2014).

Growth indexes, such as foliage surface, foliage surface index, net assimilation rate, and crop growth rate are indicators that permit a qualitative description of growth. Its components are relatively simple and enable analysis and comparison of the capacity of plants to grow and develop in a particular environment overtime (Lambers et al., 2008).

Sugarcane is the crop with the highest production of useful biomass for ruminant nutrition. Cultivars grown in dryland conditions only need irrigation during the establishment. The plant shows high yields with little chemical fertilization in the humid and sub-humid tropical regions. It is the only poaceae that increases nutrient content with age. It helps prevent the costs of preserving the excess production during the rainy season, along with forage cuts at that time. It has a high genetic variability, so there are cultivars for most tropical and subtropical environments. All the cultivars are easily adapted to all the edaphoclimatic conditions. The plantations may be active for many years if properly handled. The harvest could be mechanized or manual, both with high productivity (Bastidas et al., 2012; Siqueira et al., 2012; Ramírez-Cathí et al., 2014; Bezerra et al., 2017; Salazar-Ortíz et al., 2017).

Bastidas et al. (2012) said that the agronomic evaluation of forage-producing species should not only rely on the final harvest; it may not show the particular effect of the environmental factors on the productive capacity of plants throughout their biological cycle. Therefore, describing their physiological behavior, production, and nutritional composition is significant (Bárcena et al., 2009). Hence, plant growth analysis is a valuable tool to know biomass formation and accumulation determined by the plant's internal factors and the environment it grows (Calzada et al., 2014).

This paper aims to characterize the growth dynamic of sugarcane cultivars C97-366 and C99-374 with forage purposes.

Materials and Methods

The study was done at the Mid-Eastern Territorial Sugar Cane Research Station (ETICA), located in the municipality of Florida, Camaguey, Cuba, on the following coordinates: 21º 31' north latitude and 78º 04' west longitude, 57.08 m above sea level. The field experiment was conducted in brown soil with carbonates, according to Hernández et al. (2015).

The climatic variables were recorded at the Agrometeorological Station in Florida, 600 m away from the field experiment. The relative humidity during the study had a mean of 76.59%; the average temperature was 25.6 ^{0}C. The total of precipitations was 1 203.6 mm in 105 days of rain.

Sugarcane cultivars C97-366 and C99-374 selected by the Plant Breeding Department at the Mid-Eastern ETICA, in Camaguey, for forage production, were evaluated. The experiment was based on a randomized experimental block design with three replicas. The experimental area of each unit was 63 m^2 (14 m x 4.5 m), three 14 m long rows for cultivation. The plantation was performed in the second fortnight of August 2014, in dryland conditions The agrotechnical work was done according to the standards set for the crop (Santana et al., 2014).

The plant growth indicators evaluated were foliage surface, foliage surface index, net assimilation rate, and crop growth rate. The evaluations were made monthly. Sample collection was started in February 2015, at 181 days of plant age, and up to July 2015, 342 days after planting. Each replica needed three representative samples by cultivar at every age evaluated. Each sample contained a stem with leaves and shoots, which was cut at the soil level, using a machete.

The leaves with over 50% of their photosynthetic area were considered active. The dry mass of laminae and active leaf pods, shoots, and stems, were determined. All plant parts were weighed by separate using a technical balance to determine the dry mass, and were sectioned. Then they were exposed to sunlight in a greenhouse, reaching ± 7 ^{0}C above the room temperature. Upon losing most humidity, they were dried in a stove (65 ^{0}C) to reach a constant weight. The dry mass of all plant parts was determined. The total weight by individual was determined by summing the biomass data (dry mass).

The data of the nine individuals by cultivar were used to determine every growth indicator, including the foliage surface. The growth analysis was performed according to Kvet et al. (1971), as follows:

Determination of foliage surface: (A)

To know the total foliage surface per individual, the length and width of all the active laminae were measured. Each lamina surface was calculated by multiplying length by width and factor 0.7 (Lerch et al., 1977). The sum of all the factors represents the foliage surface of every individual, expressed in cm^2.

A = ANLB x LGLB x 0. 70

- ANLB = Limb width, taken from the widest portion of the lamina (cm), with up to 1 mm accuracy.
- LGLBB = Limb length, measured from the apex to the pod insertion (cm), with up to 1 mm accuracy.

Determination of foliage surface index: (IAF)

It was calculated by dividing the foliage surface (m^2) between the land area.

IAF = A / At (m^2 m^{-2})

- A = Foliage surface with over 50% of active foliage lamina (m^2).
- At = Land area (m^2).

Determination of crop growth rate: (TCC)

It was calculated by dividing the difference of the total dry mass of the plant between the land area product by the time difference that mediates between sample collections.

TCC = $W_2 - W_1$ / At ($t_2 - t_1$) (g m^{-2} day^{-1})

- W_1 = Total plant dry mass overtime 1. (g).
- W_2 = Total plant dry mass overtime 2. (g).
- $t_2 - t_1$ = Time interval of evaluation (days).
- At = Land area (m^2).

Determination of the net assimilation rate: (TAN)

As much as twice the difference of the plant total dry mass was calculated, then it was divided between the product of the foliage surface sum by the time difference that mediates between sample taking.

TAN = 2 x (W2- W1) / (A1 + A2) ($t_2 - t_1$) (mg cm^{-2} day^{-1})

- W_1 = Total plant dry mass overtime 1. (g).
- W_2 = Total plant dry mass overtime 2. (g).
- A_1 = Foliage surface with over 50% of active foliage lamina overtime 1 (cm^2).
- A_2 = Foliage surface with over 50% of active foliage lamina overtime 2 (cm^2).
- $t_2 - t_1$ = Time interval of evaluation (days).

A database containing all the information collected during the evaluations was set up for statistical processing. Correlation analyses were made to determine the mathematical models that describe the growth indicators evaluated. A variance analysis was performed to validate the equations of the models obtained. STATGRAPHICS Centurion for Windows, version 15.1 (2006) was used for statistical analysis.

Results and discussion

The foliage surface (A) describes the size of the assimilation organ (leaf) of a plant. Its development is critical for production, by maximizing the intersection of solar radiation and the accumulation of biomass (Endres et al., 2018).

Fig. 1 shows the behavior of this growth indicator (A) in C97-366 and C99-374, from day 181 and until 342 after planting. As shown, the cultivars were fit to a third order polynomial equation, with significant ($p<0.05$) determination coefficients (r^2 = 98.41 and r^2 = 98.42) that validate the model.

It also shows that the behavior of the foliage surface was highly variable during the study; the least values were achieved in the first two evaluations, in February and March, at plantation ages of 181 and 215 days, respectively. Particularly, cultivar C99-374 reached the highest value at 342 days (52.29 dm^2), whereas C97-366 reached it at 277 days (49.87 dm^2)

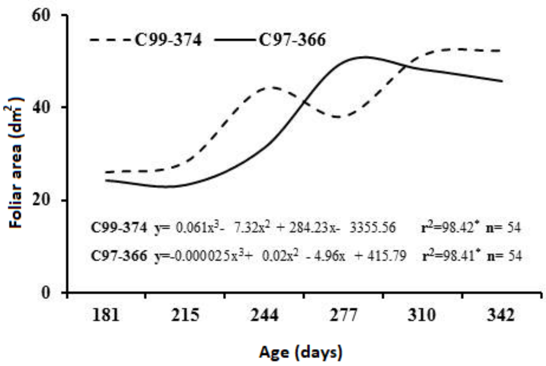

Fig. 1. Behavior of foliage surface (A)

These results are attributed to the prevailing climate conditions observed during the study, where the monthly precipitations and the mean monthly temperature played a major role in sugarcane growth (Fig. 2).

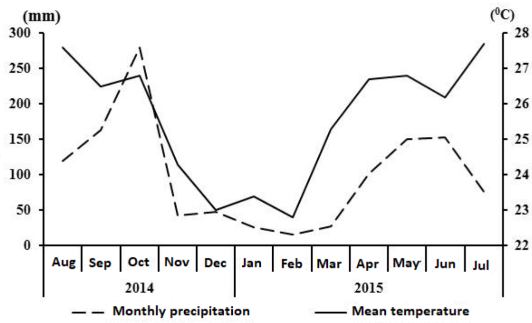

Fig. 2. Behavior of climatic variables throughout the study

Fig. 2 corroborates the previous; in February and March, the lowest records or precipitations and mean temperature occurred, below the upcoming months evaluated.

These results corroborate the reports of Ejaz et al. (2011) that water was not always present in the desired quantity during all the growth phases of the crop, and very importantly, the presence of water stress not only brought about a reduction of foliage, but also caused considerable losses to yields.

Torres (2006) reported lower values in terms of foliage surface in a study of growth indicators of three sugarcane commercial cultivars grown in the same edaphoclimatic conditions, whose plantation evaluations in the cold season coincided with the ones reported in this research.

This results has a relevant practical value, as it demonstrates the high green biomass production from foliage by the two novel cultivars of sugarcane (C97-366 and C99-374) selected for use as forage production to feed ruminants.

The high foliage values observed by the two new cultivars (April-July), which coincided with the period of accelerated growth, are important for forage production, considering the study done by Echarte et al. (2008), who noted that an increase of the foliar surface leads to a rise in the dry matter accumulation rate (light interception is directly related to the duration of the foliar surface in this stage of development), while an increase of dry matter accumulation leads to higher foliar surface (the dry matter proportion in the leaves is quite constant).

IAF permits the estimation of the photosynthetic capacity of plants, and helps understand the relation between biomass accumulation and low yields under the prevailing environmental conditions in a particular area (Endres et al., 2018). Fig. 3 shows the behavior of this growth indicator (IAF) in C97-366 and C99-374, from day 181 and until 342 after planting.

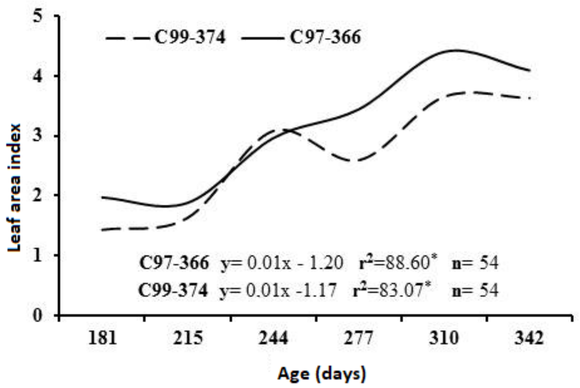

Fig. 3 Behavior of foliage surface index growth indicator (IAF)

As shown, the sugarcane cultivars were fit to a linear equation, with significant ($p<0.05$) determination coefficients (r^2 = 83.07 and r^2 = 88.60) that validate the model. Biologically, the linear equation obtained indicated that the two cultivars increased their surface daily (0.01 m^2) in terms of foliar surface per each m^2 of land area (Fig. 3).

These results can also be attributed to the prevailing climatic conditions during its development (Fig. 2). As the monthly evaluations took place, the recorded precipitations and temperatures produced favorable conditions for crop development.

The IAF value observed in C97-366 at 277 days may be considered optimum (3.44), and from that plantation age to 342 days, the values were above the optimum. The particular case of C99-374 reached the optimum values at 244 (3.08), at 310 and 342 days, with values above the optimum range for the crop (Fig. 3). All the criteria corroborate Hui et al. (2009), who said that the crop's canopy from the six upper leaves intercept 70% of the solar radiation, and that the leaves' photosynthetic rate diminishes because of mutual shading. Therefore, an effective utilization of solar energy by IAF, within 3.0-3.5 is thought of as optimum.

In a study where three sugarcane cultivars with different maturing dynamics were evaluated in two planting cycles, Torres et al. (2015) reported mean IAF values of 2.47, and 2.55 m^2 m^{-2}, from the spring and winter cycles, respectively. The two new forage-producing cultivars overcame those results with higher increases (over 60%) than that indicator. It demonstrates the potentialities of these two genotypes for the biomass production purposes they were selected. It is a highly significant indicator to estimate sugarcane yields, for its relation to the interception of radiation and precipitations, energy conversion, and water balance (Srinivasan et al., 2017; Endres et al., 2018). In turn, Jun et al. (2013) found a positive correlation between IAF and dry matter accumulation.

Fig. 4 shows the behavior of indicator TCC in C97-366 and C99-374, from day 181 and until 342 after planting. As seen, C99-374 was fit to a third order polynomial equation, and C97-366, to a linear equation. The two cultivars showed significant ($p<0.05$) determination coefficients (r^2 = 98.68 and r^2 = 91.47) that validate the models.

These results evidence that the genotypes studied did not have the same behavior over time, regarding TCC, which was corroborated by Calheiros et al. (2012), a complex parameter determined by a number of physiological, morphological, and biomass increase components of each genotype in particular.

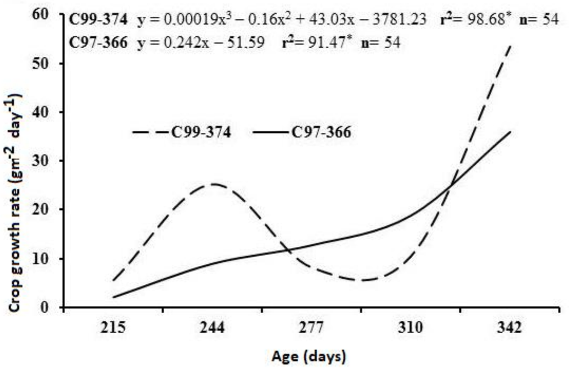

Fig. 4 Behavior of growth indicator crop's growth rate (TCC).

Fig. 5 shows the behavior of indicator TAN in C97-366 and C99-374, from day 181 and until 342 after planting. As seen, C99-374 was fit to a third order polynomial equation, and C97-366, to a linear equation. The two cultivars showed significant ($p<0.05$) determination coefficients (r^2 = 99.99 and r^2 = 98.47) that validate the models.

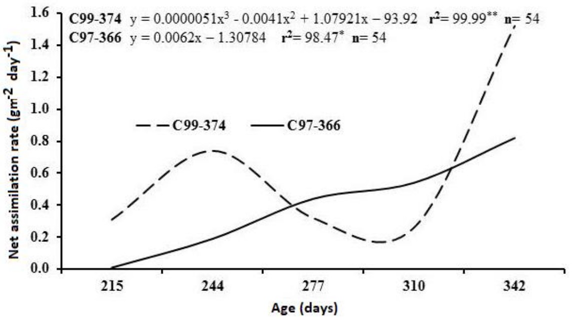

Fig. 5 Behavior of growth indicator net assimilation rate (TAN).

During the last evaluations both cultivars showed an increase of this indicators (TAN), which may be attributed to a rise in precipitations (amount and days), and an increase of the mean temperature values recorded in the preceding months (May-June). It confirms the findings of Larios (2016), when he noted the importance of the climatic factors in the production of biomass and the accumulation of dry matter from sugarcane.

This is a relevant indicator in terms of forage production, since it represents the speed of plant dry weight increment by foliar surface unit. This net weight increase results from the balance of photosynthesis and breathing (Barrera et al., 2010).

Torres (2006) published lower results in relation to TCC and TAN, in a study involving three commercial sugarcane cultivars. It evidenced that the new forage-producing cultivars have morphological features that confer them more efficiency in biomass production.

Conclusions

Sugarcane cultivars C97-366 and C99-374 showed genetic and morphological characteristics that enable them perform efficient physiological processes that determine proper biomass production for ruminant nutrition.

Author contribution statement

Yoslen Fernández Gálvez: research planning, template process, analysis of the results, redaction of the manuscript, final review.

Yaima de las Mercedes Daniel Ortega: research planning, analysis of the results, redaction of the manuscript, final review.

Redimio Manuel Pedraza Olivera: analysis of the results, redaction of the manuscript, final review.

Yoslen Fernández Caraballo: experimental mounting and evaluation, analysis and interpretation of the results.

Modesto Ponce Hernández: analysis of the results, redaction of the manuscript, final review.

Arelys Valido Tomes: analysis of the results, redaction of the manuscript, final review.

Conflicts of interests

The authors declare the existence of no conflicts of interest

References

Bárcena, G. R., Hernández, P. A., Meneses, M., Ramírez, E., Crosby, M. M., & Lee, A. (2009). *Guía Práctica. Composición nutrimental y valor nutritivo de los forrajes del Estado de Puebla.* Fundación PRODUCE.

Bastidas, L., Rea, R., De Sousa Vieira, O., Hernández, E., & Briceño, R. (2012). Análisis de variables agronómicas en cultivares de caña de azúcar con fines azucareros, paneleros y forrajeros. *Bioagro*, *24*(2), 135-142. http://bioagrojournal.com/index.php/path/article/view/142/143

Bezerra, J. D. C., Ferreira, G. D. G., Campos, J. M. de S., Oliveira, M. W. de, Andrade, A. P. de, & Nascimento Júnior, J. R. S. do. (2017). Biometric and chemical characteristics of sugarcane varieties for use as forage in limiting soil water conditions. *Revista Brasileira de Zootecnia*, *46*(5), 384-392.

https://doi.org/10.1590/S1806-92902017000500003

Calheiros, A., Oliveira, M., Ferreira, V., Barbosa, G., Santiago, A., & Aristides, E. (2012). Production of biomass, from sugar and protein in function of sugarcane varieties and phosphorous fertilization. *Semin. Cien. Agrar.* *3*(12), 809-818. http://dx.doi.org/10.5433/1679-0359.2012v33n2p809

Calzada, J., Enríquez, J., Hernández, A., Ortega, E., & Mendoza, S. (2014). Análisis de crecimiento del pasto maralfalfa (*Pennisetum* sp.) en climas cálidos subhúmedos. *Cienc Pecu*, 5 (2), 247-260. http://www.scielo.org.mx/scielo.php?pid=S2007-11242014000200009&script=sci_arttext

Endres, L., dos Santos, C. M., de Souza, G. V., Menossi, M., & dos Santos, J. C. M. (2018). Morphological changes recorded in different phenophases of sugarcane plants subjected to water stress in tropical field conditions. *Australian Journal of Crop Science*, *12*(07), 1041-1050. https://search.informit.org/doi/10.3316/informit.881611792651534

Fortes, D., Herrera, R., García, M., Cruz, A., & Romero, A. (2014). Growth analysis of the Pennisetum purpureum cv. Cuba CT- 115 in the biomass bank technology. *Cuban Journal of Agricultural Science*, *48*(2), 167-172. www.cjascience.com/index.php/CJAS/article/download/477/444

Hernández, J. A., Pérez, J. J. M., Bosch, I. D., & Castro, S. N. (2015). *Clasificación de los suelos de Cuba.* Ediciones INCA. http://ediciones.inca.edu.cu/

Hui, L., Jinsong, C., Zhiyuan, P., Songling, Z., & Xianzhi H. (2009). Monitoring Sugarcane Growth Using ENVISAT ASAR Data. IEEE Transactions on Geoscience and Remote Sensing, *47* (8), 2572-2580. https://ieeexplore.ieee.org/document/4838866

Jun, L., Youxiong, Q., Hua, Z and Liping, X. (2013). Seasonal Variation of the Canopy Structure Parameters and Its Correlation with Yield-Related Traits in Sugarcane. *Scientific World Journal*, 80(1), 486-490. http://dx.doi.org/10.1155/2013/801486

Kvet, J., Ondok, J.P., Necas, J., & Jarvis, P. G. (1971). Methods of growth analysis. En *Plant Photosynthetic Production. Manual of Methods.* Dr. W., Junk, N. V. Publishers.

Lambers, H., Chapin, F., & Pons, T. (2008). *Plant physiological ecology*. (2da.ed). New York, EE. UU: Springer - Verlag. http://www.esalq.usp.br/lepse/imgs/conteudo_thumb/Plant-Physiological-Ecology-by-Hans-Lambers--2008-.pdf

Larios, M. (2016). *Calidad nutricional de tres forrajes tropicales cosechados a diferentes edades de corte en Zamorano, Honduras*. (Trabajo de grado, Ingeniero Agrónomo). Escuela "Agrícola Panamericana", Tegucigalpa, Honduras. https://bdigital.zamorano.edu/bitstream/11036/5854/1/CPA-2016-T059.pdf

Lerch, G., Reyes, R., García, R, & Leal, P. (1977). Crecimiento, desarrollo, y variación del índice refractométrico (Brix) en seis variedades destacadas de caña de azúcar. *Ciencias de la agricultura*, *1*(6), 79-105.

Ramírez-Cathí, H., Salcedo-Martínez, A. C. C., Briones-Encinia, F., Cárdenas-Lara, A., Lucero-Magaña, F. A., Marcof-Álvarez, C. Sánchez-del Real, C., & Martínez-González J. C. (2014). Sugar cane tops (Saccharum officinarum) in the finalization of pelibuey sheep during the dry season in the tropics. International *Journal of Research. Agriculture and Food Sciences*, 2(1), 21-25. http://ijsk.org/uploads/3/1/1/7/3117743/4_animal_husbandry.pdf

Salazar-Ortiz, J., Trejo-Téllez, L.I., Valdez-Balero, A., Sentíes-Herrera, H.E., Rosas- Rodríguez, M., Gallegos-Sánchez, J., Crosby-Galván, M.M., & Gómez-Merino, F. C. (2017). Caña de azúcar (Saccharum spp.) en la alimentación de rumiantes: experiencias generadas con cañas forrajeras. *Agroproductividad*, *10*(11), 70-75. https://mail.revista-agroproductividad.org/index.php/agroproductividad/article/view/62/57

Santana, I., Santos, J., Guillén, S., Sánchez, M., Velarde, E., Jorge, H., Sulroca, F., De, M., Benítez, L., Zambrano, Y., & Acevedo, R. (2014). *Instructivo Técnico para la Producción y Cultivo de la Caña de Azúcar.* Pueblo y Educación.

Siqueira, G. R., Roth, M. de T. P., Moretti, M. H., Benatti, J. M. B., & Resende, F. D. de. (2012). Uso da cana-de-açúcar na alimentação de ruminantes. *Revista Brasileira de Saúde e Produção Animal*, *13*(4), 991-1008. https://www.scielo.br/j/rbspa/a/QBnZRT7gc4TfPwdBNSDH57j/?format=pdf&lang=pt

Srinivasan, V., Kumar, P., & Long, S.P. (2017). Decreasing, not increasing, leaf area will raise crop yields under global atmospheric change. *Global Change Biol.*, *23*(4), 1626–1635. https://doi.org/10.1111/gcb.13526

STATGRAPHICS Centurion/PC para Windows Paquete estadístico. Versión. 15.1. [Programa de computación]. (2006). [s.n.].

Torres, I. (2006). *Indicadores de desarrollo en tres variedades de caña de azúcar (Saccharum* *híbrido) plantadas en primavera y frío.* (Tesis de Maestría). Universidad de La Habana.

Torres, I., Valladares, F., Montalván, J., Fernández, Y., Noy, A., Padrón, M. Pousa, I., Díaz, C., Quiñones, I., León, P., Cervantes, O., & Hernández, J. (2015). *Indicadores fisiológicos como herramienta para la selección de cultivares en caña de azúcar.* (Ponencia). XXXVII CONVENCIÓN Y EXPOATAM. Veracruz, México. https://www.atamexico.com.mx/wp-content/uploads/2017/11/3-VARIEDADES-2015.pdf

Wilson García, C. Y., Hernández Garay, A., Ortega Cerrilla, M. E., López Castañeda, C., Bárcena Gama, R., Zaragoza Ramírez, J. L., & Aranda Osorio, G. (2017). Análisis del crecimiento de tres líneas de cebada para producción de forraje, en el valle de México. *Revista De La Facultad De Ciencias Agrarias UNCuyo*, *49*(2), 79–92. https://revistas.uncu.edu.ar/ojs3/index.php/RFCA/article/view/3042