

Physiological Response of Sugarcane (*Saccharum spontaneum*, cv US 67-22-2) to
Nitrogen Levels

By

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To my grandparents Salvio Torres-Bracero (Papunka) and David Justiniano-Justiniano (Papa David). Thanks for being so extraordinary human beings, for your excellent life examples and your unconditional love. I'll be always very proud about you.

ABSTRACT

This experiment quantified the agronomical and physiological response of environmental cane US 67-22-2 to N fertilization levels, and developed mathematical relationships between dependent traits and independent climatological parameters. A preliminary greenhouse experiment, was the foundation for the design of a field experiment conducted on a Vertisol soil at Puerto Rico, in which the sugarcane response to four N levels (0, 448, 896, 1344 Kg N/ha) and three harvest intervals (HI) (240, 270, 300 days after planting) was studied. At the greenhouse experiment and in terms of leaf area, plant height and number of leaves, the plants with N were significantly superior to the control, and statistically similar among them. At the field experiment it was observed that the application of 448 Kg N/ha is enough to obtain adequate plant cane yield, photosynthetic rate and relative chlorophyll content. The optimum dry matter yield (25,811 Kg/ha) was obtained at 300 days HI.

RESUMEN

Este experimento midió la respuesta de la variedad de caña US 67-22-2 a niveles de N y desarrollo relaciones matemáticas entre variables dependientes y parámetros climatológicos independientes. Un estudio preliminar de invernadero sirvió como base para el experimento de campo realizado en un suelo Vertisol, en el cual se estudio la respuesta de la caña a cuatro niveles de N (0, 448, 896, 1344 Kg/ha) y tres intervalos de cosechas (IC) (240, 270, 300 días). En el invernadero y en términos de área foliar, altura de planta y número de hojas. Las plantas con N resultaron significativamente superior al control y estadísticamente similares entre ellas. En el experimento de campo se observo una producción adecuada, una buena tasa fotosintética, y un buen contenido relativo de clorofila con la aplicación de 448 Kg N/ha. La producción optima de materia seca (25,811 Kg/ha) se obtuvo a un IC de 300 días.

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CHAPTER 1

Introduction

1.1 SUGARCANE WORLD PRODUCTION

During 2004, the world sugarcane (*Saccharum officinarum* L.) harvested area was 20,287,184 ha with a production of 1,323,951,982 Mt (FAOSTAT). Sugarcane is the main source of sugar in all tropical and subtropical countries of the world. Several species of *Saccharum* are found in south East Asia and neighboring islands, and from this cultivated cane probably originated. The sweet juice and crystallized sugar were known in China and India some 2500 years ago. Sugarcane reached the Mediterranean countries in the eight-century A.D., and reached the Americas in early colonial times.

1.2 SUGARCANE HISTORY IN PUERTO RICO

In Puerto Rico the sugarcane crop became the most important crop in the first half of the twentieth century. During those years Puerto Rico and Cuba became the two countries with the highest yields of sugarcane in the Caribbean, and the latest technology including state of the art sugar mills. Wasteful, old colonial “ingenios” were replaced by efficient, modern sugarcane processing plants. For example, the introduction of new varieties of sugarcane caused a 20% increase in sugar production in 1923-24 alone. These new varieties sometimes made the process of refining easier by providing softer canes for roller grinders, burning fuel for boilers, and richer syrups. But the introduction of new varieties into the field also created genetic homogeneity, which made the crops susceptible to new diseases. To catch up, scientists then had to develop fresh hybrids, which set off another cycle of the changes. Scientists in Puerto Rico became incredibly productive worldwide famous in the sugar industry and most of the countries with the most prosperous sugarcane programs became in contact with Puerto Rico scientists. Puerto Rico was leading the sugarcane industry in this side of the hemisphere. By those days the island economy was almost totally dependent on agriculture. After the

commonwealth political status was established in the fifties, a new economic approach was followed transforming the economy from an agricultural to an industrial one. Among the most dramatic impact was suffered by the sugarcane; from an average yield of 9.7 million tons during the decade of the 60's, to 782,000 tons in 1990 and zero after 2002-03 growing season.

Actually, although the government is presenting some incentives for sugarcane farmers and the private industry has expressed their desire to establish sugarcane plantations for the production of molasses for the local rum industry, it is uncertain if this industry will be reestablished. Under this scenario, it is time for agricultural researchers to demonstrate to the local government that Puerto Rico continues with the agricultural potential to contribute significantly to the economy.

1.3 SUGARCANE IN THE UNITED STATES

According to Salassi, M.E. and Legendre, B.L., in the United States (U.S.) the agriculture represents almost 50% of the total economy, being sugarcane one of the main tropical crops. U.S. sugarcane production was 4,082 million short tons in FY 2001. Florida and Louisiana account for the bulk of sugarcane acreage. During FY 2001 the sugarcane production at Florida was 1.990 million short tons from an estimated 446,000 harvested acres, representing an average of 35.3 tons/acre, a yield comparable with the best ones worldwide. At Louisiana for the same period the sugarcane production was 1.610 million short tons from harvested acreage of 460,000 acres, representing an average of 30 tons/acre.

1.4 BIOMASS PRODUCTION POTENTIAL

Sugarcane is also one of the best crop examples for biomass production. The remainder of the plant once the sugar is extracted is called bagasse that still contains the chemical energy of the sun. Scientists worldwide are trying to develop ways to burn biomass as an alternate fuel. When burned, biomass does release carbon dioxide consumed through photosynthesis when biomass crops are grown.

1.5 NITROGEN RECOMMENDATIONS FOR PUERTO RICO

The sugarcane industry in Puerto Rico or elsewhere is a major user of nitrogen fertilizer and has an interest in efficient fertilization practice to limit costs and ensure a sensitive environment is not exposed to excessive nitrogen losses. Current nitrogen fertilization recommendations for Puerto Rico are broad and unrelated to any field specific measures of plant or soil N status.

1.6 ENVIRONMENTAL/ENERGETIC SUGARCANE PROGRAM

During the 70's and 80's Dr. Alex Alexander, a scientist from the University of Puerto Rico developed a strong sugarcane research program, in which numerous new varieties were developed for the conditions of the island emphasizing not only sugar yields, but also biomass production. From those varieties, US 67-22-2 has been selected to observe its response to different nitrogen levels applications in a clay soil at Lajas, Puerto Rico.

The unique capacities of US 67-22-2 for sustained growth and hardiness are underwritten by its potential to convert radiant solar energy and atmospheric carbon to usable forms of chemical energy. The photosynthetic processes employ electrons from water to reduce atmospheric carbon to carbohydrate forms (“photosynthates”). Sucrose is the source of carbon and energy needed to sustain plant life processes including the massive growth activities of environmental cane. The crop is one of the best alternatives to control soil erosion, fix atmospheric carbon improving soil properties and preserving watershed degradation.

1.7 RECENT ADVANCES IN AGRONOMY

During the past century agriculture has undergone many fundamental changes, including extensive dependence on farm machinery, intensive fertilizer and agrochemical management, crop breeding, high yielding hybrids, and genetic manipulation. Current projections suggest that within five years only 200,000 growers will produce 85% of

American agriculture. The continuation of current trends will create strong pressure for improved grower efficiency. The development of spatial information technologies like satellite and airborne remote sensing, Geographic Information Systems (GIS) and Global Positioning Systems (GPS) along with high speed computers and satellite communications have created new opportunities that will change the way agriculture is practiced. For instance, instead of management for standard protocols we have the capability to make decisions and effectively manage fields at highly precise spatial detail. In many places in the literature these information intensive technology is sometimes referred to as precision agriculture or site specific agriculture. Within this new agricultural era we are able to measure the amount of energy radiating from a surface in a particular portion of the spectrum using a radiometer. Radiometers can be handheld for research purposes and monitoring small field plots to survey entire fields, farms, or agricultural regions.

1.8 OBJECTIVES

This research was conducted to quantify the physiological response of environmental cane to nitrogen fertilization and to develop mathematical relationships between those physiological traits and independent climatological parameters such as degree days, and nitrogen fertilization levels. Upon development, these mathematical growth functions can be used to predict biomass accumulation and maximum atmospheric carbon fixation potential of the crop.

CHAPTER 2

LITERATURE REVIEW

2.1 WORLDWIDE RESEARCH

Judicious use of fertilizers is essential for optimum economic response. This precludes either over or under fertilizing and also entails applying at the right time, in the right form and in the right place. In sugarcane, amounts to be added are based on experimental trials together with the results of soil analysis and foliar diagnosis. However, there is still room for more precise recommendation based on soil type and climate.

In Venezuela, Segura (1971) evaluated four levels of N, P, and K during three harvests in sugarcane. When no N was applied, the sugarcane yielded 80 tons less of cane and 7-ton less of sugar as compared with the application of 150 Kg of N/ha/harvest. The P must be applied only at planting, being the application sufficient until the second ratoon.

In Florida, Gacho (1983) determined that the highest sugarcane yields were obtained at N rates of 224 and 448 kg/ha for plant-cane and first ratoon crops, respectively. Gacho (1983) also reported that the cultivars tested had different N use efficiencies. Sugarcane yield of cultivar cp 72-1210 on a sandy soil was greater with more split applications (5 splits for plant-cane and 4 splits for ratoon) than less split applications (3 splits for plant-cane and 2 split for ratoon) at the same rate of N fertilization (224 Kg/ha/yr). However, in the second ratoon crop, the difference between number of split applications was not conclusive.

In Texas, Wiedenfeld (1995) evaluated the effect of rate and timing of N fertilizer applications on sugarcane growth, and determined optimum fertilization practices for sugarcane yield on clay soils. As in previous studies, responses to N application did occur in the plant cane crop, but were observed in the first through third rations. Early fertilizer applications resulted in lower sugar yield due to lower juice quality rather than any loss in growth. N fertilizer application to sugarcane on clay soils in subtropical south Texas

was not required on plant cane crops, and should be at least at or above the level of 224 kg/ha in ratoon crops.

In Brisbane, Qld., Keating (1998-99) continued the approach of other researchers applying the “N at the mill” technique for assessment of crop N status. This technique uses a measure of amino-N levels in sugarcane at harvest time to indicate the degree to which a crop was under or oversupplied with N. Results indicated that approximately half of the sugarcane rakes samples registered amino-N levels indicative of higher than desirable N supply.

Verburg et al. (1998) evaluated the APSIM (Agricultural Production Systems Simulator) in the nitrate leaching under sugarcane. Their study highlighted the complex interactions between crop yield, soil type, weather, and nitrate leaching, and hence the importance of considering the whole system when examining management scenarios. The illustrated seasonal variability in nitrate leaching and the limited effect of split nitrogen fertilizer application showed that significant carry-over effects from previous years needed to be taken into consideration. This finding applies not only to simulations, but also to experiments, as often confirmed by the absence of N response observed in the first year of cropping trials. The result also suggests that if N-fertilizer rates are matched to plant requirements and fertility status nitrate leaching could be reduced.

In France, Cruz and Guillaume (1999) evaluated the growth and mineral nutrition of sugarcane under planting or ratoon cropping conditions. Among their objectives was to test N nutrition assessments according to critical curves for N% in sugarcane stands. The fitted curve for N% of sugarcane crops with high N fertilization was lower than the critical curve for C4 species, due to the very high specific leaf weight of sugarcane, which limits the N concentration in leaves when expressed on a dry matter basis. They concluded that the curves linking N% and crop biomass provide a satisfactory assessment of N nutrition levels with sugarcane crops.

O’leary et al. (2000) evaluated the addition of a soil and plant N sub model to the CANGEGRO sugarcane simulation model. This increased the accuracy of sucrose yield prediction by removing some bias, despite a greater variance and a generally weak N

uptake performance. The new model will enable the effects of N deficiency in sugarcane to be studied and managed within the context of variable weather, management and soils in similar ways to water resources with current non-N models. It should also assist farmers to determine ways to optimize N applications and reduce volatilization losses and the risk of groundwater pollution from overuse of N fertilizer, especially in irrigated regions.

In Louisiana, Hallmark et al. (2001) performed fertility studies to help optimize sugarcane profits. Their results showed that applying 50 to 60 pounds of N/ acre to plant cane at four test sites resulted in as good sugar yield and producer profits as where the recommended rate (150 to 180 pounds of N/acre) was used. Applying more than the recommended rate did not result in higher sugar yields or producer profits at four tests sites, and actually reduced sugar yields by 630 pounds/acre (\$83/acre) at one site. Their results indicated that sugarcane producers should avoid over fertilizing with N and that they could reduce N rates with plant cane. Results with first ratoon showed that applying 100 to 120 pounds of N/acre resulted in as high sugar yield and producer profit as where the recommended rate (140 to 160 pounds/acre) was used. Their research indicated that first ratoon should not be over fertilized with N, and it may require less N than is currently recommended. Results with second and third ratoon indicated that the recommended rate of 140 to 160 pounds/acre was consistent with optimal sugar yields and producer profits.

In Louisiana, Brown and Hawkins (2001) evaluated the use of an N stabilization package (N-hib Ca, composed of calcium chloride, magnesium chloride, and a urease inhibitor) and liquid urea, to increase yields and reduce the N requirements of sugarcane. Urea and the N stabilization package were applied in all possible combinations. N rates were: 0, 67, 134, and 201 Kg /ha; and calcium rates from the stabilization package were 0, 22, and 44 Kg/ha. Adding 44 Kg Ca/ha as N-hib (a commercial product of Stoller Enterprises) Ca to 134 Kg N/ha increased sugar yields by 2,950 Kg/ha and reduced the N fertilizer requirement by 67 Kg /ha/year needed to obtain maximum yields.

Arceneaux, et al. (2001) summarized the soil fertility research in sugarcane in 2001 in cooperation with St. Gabriel Research Station and Iberia Research Station. According to the data collected ratoon crops tended to have more response to N input than plant cane. Lower yield at some locations indicated other factors may have been limiting and therefore lowered the response to N. Where there was a response, the N rate for optimum yield (>90% of maximum yield and not statistically different) was at the lower end of the recommended range or slightly below it.

In Australia, Keating et al. (2001) developed a monitoring system based on amino-N at harvest time to improve N management in sugarcane. Their research focused on the factors that influenced amino-N in cane at both plot and mill scales and prospected for an amino-N assay to identify cane crops that have experienced either insufficient or excess N supply. The large variation in amino-N in bulk cane supply at mills suggested that there is a considerable potential for improving N management, given that 30 to 60% of sugarcane sampled contained what seemed excessive concentrations of amino-N.

In Tabasco, Mexico, Salgado-Garcia, et al. (2001) studied the N fertilizer recovery efficiency (NFRE) by sugarcane ratoon submitted to different fertilization management. One experiment tested five N sources applied one month after harvesting; ammonium sulphate, urea, 20-10-10 complex, U+Triple 17, and potassium nitrate, and two fertilizer application methods: 1. superficial on top of furrow and 2. buried but applied on two dates: one month and three months after planting. When plants were 6.5 months old, they exhibited a higher NFRE with N applications made three months after initial regrowth, than applications made one month after initial regrowth.

Ehsanullah, Asif and Khalid (2001) studied the effect of different nitrogen and phosphorous levels on quantitative and qualitative of sugarcane. The significant interactive effect of 200 Kg N along with 150 Kg P_2O_5 / ha resulted in the highest cane yield of 76.64 T/ha. Increasing levels of nitrogen improved number of canes, plants height, cane length, and harvest index, whereas commercial cane sugar remained unaffected. However, increasing the phosphorous level tended to increase the commercial cane sugar.

In Australia it has been demonstrated that omitting or even halving the recommended N rate of 120 Kg/ha in alternate years, leads to serious yield losses in the rations not fertilized (Ng Kee Kwong et al. 2002). Many farmers worldwide are increasingly concerned about the gradual decline in soil fertility that often accompanies long term intensive cultivation. In North Australia, soils under sugarcane contain less organic matter and were more compacted, more acid, and were lower in cation exchange capacity and exchangeable cations. Contributing factors to soil degradation includes structural breakdown of soil and compaction due to use of equipment during cultivation and harvest, loss of organic matter due to burning of crop residues and acidification of soils due to large applications of N fertilizers (Wood 1985). In several places with a lot of potential to maximize the sugarcane industry very little information exists regarding N fertilizer management.

Nazim et al. (2003) studied the effect of nitrogen and phosphorous levels on the yield parameters of sugarcane. Four different (N:P) fertilizer levels i.e. control (0:0), 100:50, 100:75, and 200:100 Kg/ha were applied. Maximum cane stalk height (218.93 cm), maximum cane stalks weight (9.16 kg) and maximum cane yield (91.62 T/ha) were obtained from Mardan-93 variety at 100:50 NP level Kg/ha.

Muchovej and Newman (2004) studied the nitrogen fertilization on sugarcane on a sandy soil in terms of yield and leaf nutrient composition. Three rates of N fertilizer (170, 280, and 390 Kg/ha) were evaluated. The N rates were surface applied next to the row in four split applications at 8 weeks intervals. Samples were taken 4.5 and 4.0 week following the later three applications of fertilizer in the first ratoon and second ratoon crops, respectively. Leaf macro and micro nutrient concentration were not affected by the N rates. Sugarcane and sugar yields also were not affected by N fertilizer rates greater than 170 Kg/ha /yr.

Toth et al. (2002) investigated the interrelation between the photoprotective role of the xanthophyll cycle and levels of N-supply in maize plants. Plants were grown in non fertilized and fertilized plots, while the latter were supplied with 30, 60, 90, 120, and 150 Kg/ha in the form of NH_4NO_3 . The photosynthetic carbon assimilation of plants with

higher N supply, as compared to that of plants with lower N supply, showed no significant differences, although a peak of the CO₂ assimilation rate was observed at 60 and 90 kg N/ha treatment levels. Plants with lower N supply had a lower leaf chlorophyll content than plants with higher N supply, which was accompanied by a reduced rate of photochemical efficiency of photosystem II and a high thermal energy dissipation activity. The results suggested that with the decrease of N supply there is an increasing need to dissipate the excess light energy in the chloroplasts of leaves through xanthophylls cycle.

2.2 PUERTO RICO RESEARCH

Landrau and Samuels (1954) studied the response of four sugarcane varieties to fertilizers during the first Isabela cycle, 1946-51. All varieties failed to respond significantly to N applications in the plant-cane crop, while for the ratoon crops the response to 125 lbs N/acre was significant. Phosphate fertilizer gained significant increases in yields of cane for the ratoons crops while potassium fertilizers did not increase the yield of sugar per acre. Applications of nitrogen, phosphorus, and potassium did not significantly influence sucrose concentration.

Landrau, Samuels, and Alers-Alers (1959) studied the response of two sugarcane varieties to fertilizers at Rio Piedras. There was a significant increase in yield of sugar per acre from the use of nitrogen fertilizer at the rate of 150 lbs/acre and in some cases from 300 lbs/acre. There was no significant response in yield of sugar per acre from the use of phosphate fertilizers and the response due to potash fertilizer was erratic.

Samuels, Alers-Alers, and Landrau (1960) studied the influence of time of harvest and age of sixteen sugarcane varieties on their sucrose content. The sucrose content reached a peak when harvested at 10.2 months and another peak at 21.6 months. The yield of cane/acre increased with increasing cane age until 18 months when it began to decline.

González-Vélez and Samuels (1962) studied the response of sugarcane to fertilizer on an organic soil. There was no significant response to nitrogen fertilizer. The mean of

all three harvest indicated that the no-nitrogen treatment was as good as, or better than treatments where nitrogen was applied. The response to phosphate fertilizer was outstanding and the yield increased by applications of potash fertilizers, was also significant, but not with the magnitude obtained with the phosphate fertilizer.

Samuels and Cibes-Viade (1963) studied the influence of mineral deficiencies on the growth and yield of sugarcane. The elements studied were nitrogen, phosphorous, potassium, calcium, magnesium, iron, manganese, sulfur, and boron. There were differential responses to the various deficiency treatments in terms of total green weight and millable cane stalks. The absence of nitrogen and phosphorus had the greatest influence in retarding growth and yield in plants at six and half month of age. The complete treatment produced the highest yield of total green weight and millable cane for the four varieties studied.

Samuels and Alers-Alers (1964) studied the effect of time of nitrogen application on the sucrose content of sugarcane ratoon. The application of nitrogen to ratoons 15 weeks or older significantly reduced the sucrose content of the sugarcane when harvested at 12 months of age. Applications of 250 lbs of N/acre caused significantly lowering of sucrose in a three week old ratoon, while late applications of nitrogen to ratoons (15 weeks or later) reduced the sucrose percent cane even when phosphate and potash fertilizer were present.

Capo (1967) studied the applicability of a fertilizer-yield relation in sugarcane. The fertilizer yield equation fitted the data appropriately. It was recommended that sugarcane growers needed to exercise in maintaining the available nitrogen and magnesium contents of their fields as close as possible to the respective optimum concentrations than for phosphorous, potassium, and calcium.

Guindin-García (2003) conducted a field experiment at Lajas Puerto Rico to calibrate the crop simulation model CANEGRO for the high biomass cane variety US 67-22-2. Four nitrogen levels (0, 51, 101, 202 Kg/ha/yr) were evaluated. The aerial biomass accumulation did not show significant differences during eight out of nine samples taken during the experiment. In the calibration procedure several genetic coefficients were

adjusted to reach the best with the experimental data. The best fit was obtained when the phyllochron interval was set at PI 1 and PI 2 = 300. The model over predicted the accumulation of biomass possibly due to its limited ability to model water stress.

2.3 DEGREE DAYS

The effective temperature for growth and development has been defined as degree days. Various lineal and non-lineal algorithms have been developed to calculate the degree days for several crops including sugarcane. Lineal models are convenient when the temperature are not close or exceeding the optimum temperature (Summerfield and Roberts, 1987). Nevertheless, under natural conditions the temperatures are close to the optimum temperature or even higher, therefore non-lineal models are used (Yan and Hunt, 1999). In our case the degree days were calculated by determining the average between the high and low temperatures and subtracting the result from sugarcane base temperature. The CANEGRO model utilized 10 °C as base temperature to calculate degree days from planting to harvest (Guindin-García, 2003).

Alexander (1985) observed yield fluctuations in Puerto Rico during different seasons. The lower yields were obtained from November thru March, when lower temperatures are registered. According to Alexander (1973), temperatures from 28 °C to 31 °C (82 to 88 °F) are satisfactory for the optimum growth and development of US 67-22-2. The day temperature might not exceed 32 °C (90 °F) while the night temperature might not be lower than 18 °C (65 °F). Lugo-López M. and Capo (1954) observed that large temperature ranges between day and night increased the sugarcane yield while Samuels (1965) concluded that in order to mature the sugarcane needs cool temperatures.

CHAPTER 3

Materials and Methods

3.1 GREENHOUSE EXPERIMENT

As a preliminary study, an open-wall greenhouse experiment was conducted on December 2003 at the Alzamora Farm at Mayaguez Campus of the University of Puerto Rico. Twenty sugarcane seedlings, cv US 67-22-2 were planted in 20 gallons pots containing an inner silica sand medium. A completely randomized design was established in which each plant received a different N rate. Five N rates in four replications were established. N levels used were 0, 5, 10, 15, and 20 mmol/L N 1:10 ($\text{NH}_4^+ : \text{NO}_3^-$), in a complete Hoagland nutrient solution. From the third week after planting, 200 ml of nutrient solution was applied to each plant alternated with distilled water.

3.1.1 PHENOLOGICAL MEASUREMENTS

The amount of nutrient solution applied was adjusted according to plant age. Measurements (leaf area, relative chlorophyll content, photosynthetic rate, plant height, number of leaves, and number of tillers) were taken on a monthly basis. Leaf area was measured using a portable leaf area meter, model CID CI-203 (CID Inc., Camas, WA).

3.1.2 PHYSIOLOGICAL MEASUREMENTS

A Fieldscout CM-1000 (Spectrum Technologies Inc., Plainfield, IL.) chlorophyll meter was used to measure leaf chlorophyll content at leaf number two. A CO_2 analyzer LI-COR LI-6400 (LI-COR Inc., Lincoln, NE) was used for measuring leaf photosynthetic rate at leaf number two. The CO_2 mixer was set to a fixed flow at $400 \mu\text{mol s}^{-1}$ for all the measurements. The light source was used in all measurements even though they were taken in the field to avoid any possible fluctuations in the light concentration. The lamp was set to $500 \mu\text{mol m}^{-2} \text{s}^{-1}$. After calibrating the CO_2 mixer and the light source the photosynthesis measurements were taken.

3.1.3 HARVEST

All plants were harvested at 8 months after planting. After harvesting each plant was partitioned among green leaves, dry leaves, stalk, and roots. Samples were dried at 100 °C until constant weight was reached. Fresh and dry weight were taken for each sample.

3.1.4 STATISTICAL ANALYSIS

Data was statistically analyzed using Infostat. An ANOVA and a Duncan test ($p=0.05$) were performed.

3.2 FIELD EXPERIMENT

Sugarcane seedlings of cv US 67-22-2 were produced by cutting pieces of stems containing one node. Those pieces were planted in plastic trays in an open wall greenhouse containing a special soil media (Pro Mix). Seedlings were transplanted to the field three weeks after planting (August 18, 2004) at the Lajas Experimental Substation of the University of Puerto Rico, on a Vertisol (Fraternidad clay loam soil) with a cation exchange capacity of 35 meq/100g of soil. Annual rainfall is 1,194 mm, with the wettest period from August to October and the driest season from January to March. The experimental site is located at 33 meters above sea level.

3.2.1 FERTILIZER TREATMENTS

Fertilizer treatments consisted of 0, 448, 896 and 1344 Kg N/ha. Before planting a complete fertilizer (15-5-10) was applied to all plots (except 0 N) at a rate of 560 Kg/ha which represented 84, 28 and 56 Kg/ha for N, P and K, respectively. The difference for each N level (364, 812 and 1260 Kg N/ha), were divided into two equal applications and side applied using ammonium sulfate, one and five months after planting. At 0N plots, P as Superphosphate (45% P_2O_5) and K as Potassium Sulfate (50% K_2O), were applied before planting at rates of 28 and 11 Kg N/ha, respectively.

3.2.2 EXPERIMENTAL DESIGN

The experimental design was a split-plot arrangement of a completely randomized one with three replications. Each plot consisted of eight rows, 16.8 m long, spaced 1.5 m apart. Seedlings were planted 45 cm apart within the row. Nitrogen levels were the main plots and harvest intervals the subplots.

3.2.3 AGRONOMIC MANAGEMENT

Previous to planting, and for weed control, the soil was treated with Ametrine at a rate of 2.2 Kg/ha. Thirty days after planting an application of 2, 4-D was performed at a rate of 1.65 Kg a.i./ha. Before planting, soil samples were taken and analyzed to determine nitrogen concentration, soil pH, and organic matter. The experiment was conducted using standard cultural practices.

3.2.4 MEASUREMENTS

Ninety days after planting, monthly observations were performed including plant height, number of tillers, number of leaves, and leaf area. After 120 days after planting, monthly observations of photosynthetic rate and relative chlorophyll were also performed. Three harvests were made at 240, 270, and 300 days after planting. Harvest area consisted of 2 lineal meters at random within each plot.

Before each harvest, measurements were made of plant height (from the ground to the highest ligule), number of tillers, number of leaves, leaf area using LI-COR Model LI-3050A Transparent Belt Conveyer Accessory, photosynthetic rate (using Li-COR 6400) and relative chlorophyll content (using Field Scout CM-1000). Partitioned green forage yield (canopy, leaves, stem) was determined for each harvest. Partitioned samples were analyzed for dry matter content.

3.2.5 STATISTICAL ANALYSIS

Statistical analyses were performed using Infostat. Regression analyses and ANOVA were performed. Based on the ANOVA results protected LSD values ($P < 0.05$) were determined. To adjust a model to the performance of the yield components and yield to the nitrogen levels studied at different harvest intervals a non linear regression analysis (monomolecular, negative exponential formula) was used. The fitted model had the following equation $Y = \alpha (1 - \beta e^{-\gamma x})$.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 GREENHOUSE EXPERIMENT

4.1.1 LEAF AREA

In terms of leaf area, at 60 days after planting there was no significant difference between the four treatments with nitrogen. The average for these four nitrogen treatments was 1,058 cm², which represented an increase of 244% as compared with the control plant. At 120 days after planting, the plants with 15 and 20 mM N were significantly superior to the remaining ones with an average of 2,940 cm². At 180 days after planting, there was no significant difference between the four treatments with nitrogen. At that growth stage the average for these four nitrogen treatments was 7,293 cm², which represented an increase of 44% as compared with the control plant. The most dramatic change occurred between 120 and 180 days, with an average daily accumulation of 76 cm²; in other words, the plants gained 4,588 cm² of leaf area from 120 to 180 days (Figure 1).

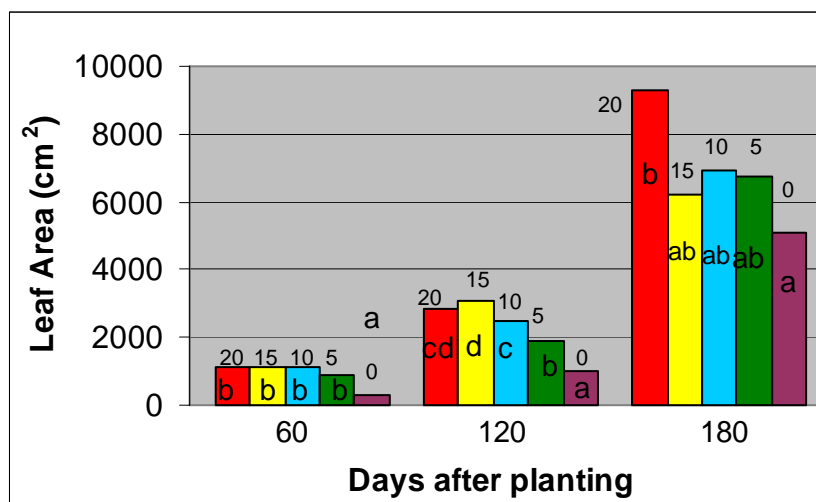


Figure 1. Leaf area of sugarcane US 67-22-2 in greenhouse experiment.

4.1.2 PLANT HEIGHT

Regarding plant height, at the three intervals the plants with nitrogen were significantly superior to the control, but statistically similar among themselves. Again, the most dramatic change occurred between 120 and 180 days after planting, with an average daily accumulation of 3 cm/day; over one inch per day. At 180 days after planting, the plant height ranged from 183 cm when no nitrogen was applied to 323 cm at 10 mM N. Interestingly, the plant height decreased 9.8 % at the maximum nitrogen level as compared with 10 mM N rate. A similar trend was also observed at 120 days (Figure 2).

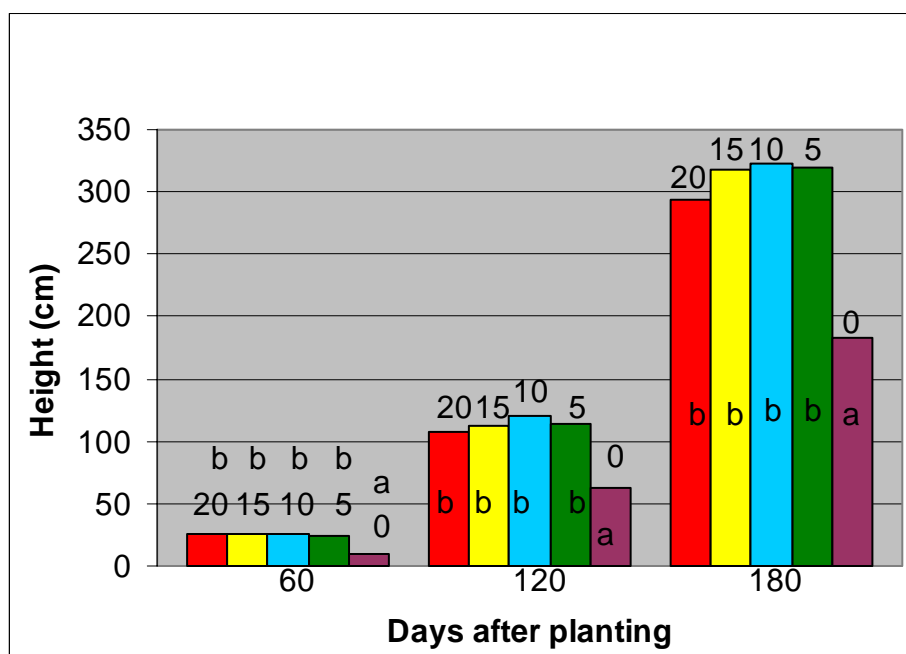
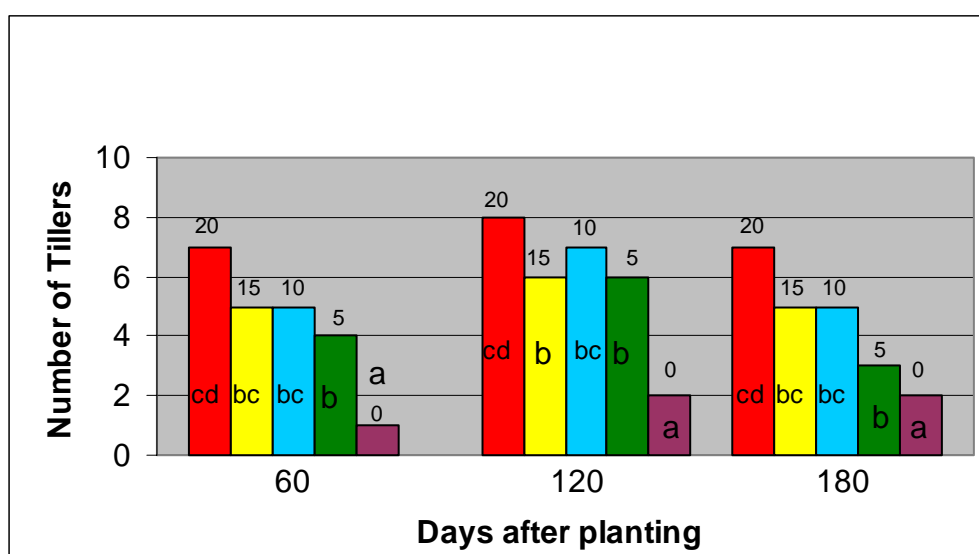


Figure 2. Plant height of sugarcane US 67-22-2 in greenhouse experiment.

4.1.3 NUMBER OF TILLERS

The average number of tillers for the four nitrogen treatments was 5.25, 6.75, and 5 at 60, 120, and 180 days, respectively. At 60 days after planting, it ranged from 1 tiller at 0 mM N to 7 tillers at the maximum N level. At 120 days after planting, it ranged from

2 tillers at 0 mM N to 8 tillers at the maximum level studied, while at 180 days after planting it remained almost similar, observing a range from 2 tillers at 0 mM N to 7 tillers at the maximum nitrogen level. At 60 and 180 days after planting, there was a clear trend at the 20 mM N level, to show the greater amount of tillers, being followed by 15 and 10 mM N treatments. It was demonstrated that with the application of nitrogen, you can move from one tiller to over eight, a huge difference that definitely will have a positive impact in the profit/acre (Figure 3).



Figure

3. Number of tillers of sugarcane US 67-22-2 in greenhouse experiment.

4.1.4 RELATIVE CHLOROPHYLL CONTENT

Leaf relative chlorophyll content was measured in leaf number two and seven from the top of the plant. A middle section of the leaf was taken for measurement. The instrument was calibrated using the chlorophyll extraction technique (Moran, 1982). The resulting calibration curve is shown in Figure 4. Regarding the leaf relative chlorophyll content, at 60 days after planting, the three highest N levels, were significantly superior to those plants receiving no nitrogen and 5 mM N. At 60 and 120 days after planting, the average for the four plants receiving nitrogen was similar (240), while that same average was reduced in 17% when plants reached 180 days after planting. At 60 days after

planting, the control plant reached only 176 or 36% less than the average of plants with nitrogen, while at 120 and 180 days the control plant registered 22% and 34% less relative chlorophyll content, than the average of plants with nitrogen (Figure 5).

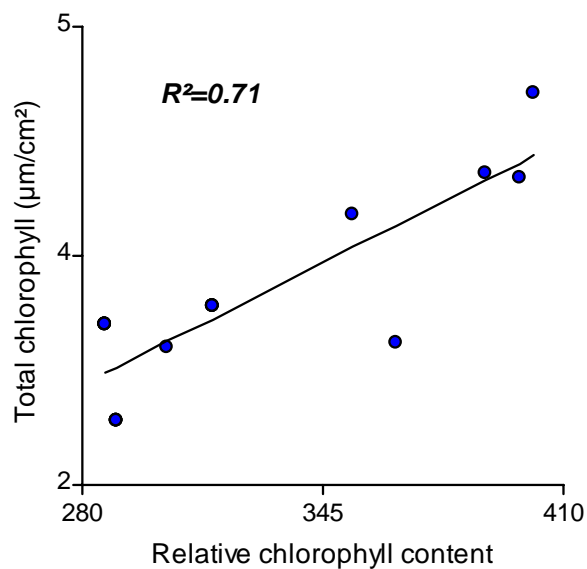


Figure 4. Chlorophyll correlation

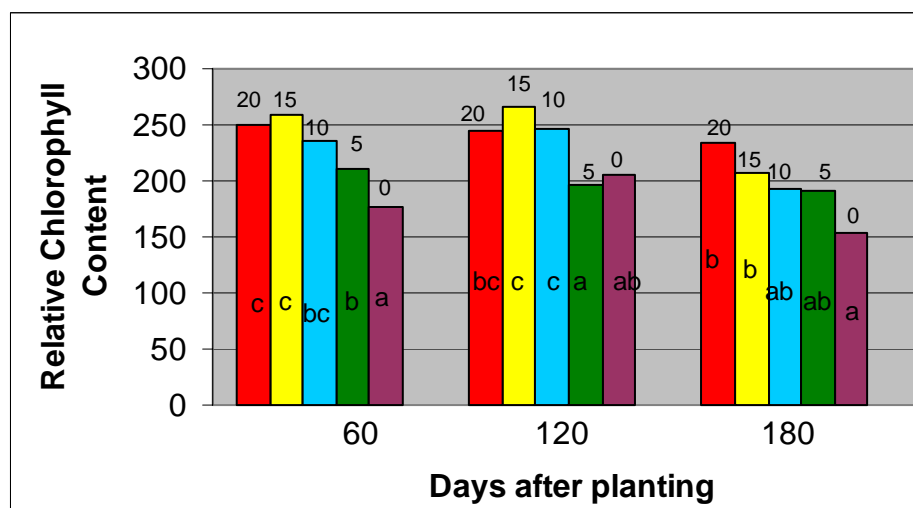


Figure 5. Leaf relative chlorophyll content of sugarcane US 67-22-2 in greenhouse experiment.

4.1.5 PHOTOSYNTHETIC RATE

At 120 days after planting the photosynthetic rate increased from 4.87 at 0 mM N to 11.58 $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$ at 20 mM N, representing this an increase of 138% in photosynthetic rate. No significant differences were observed in photosynthetic rate between the 5 mM N and the 20 mM N treatments. At 180 days after planting the photosynthetic rate increased 53% (5 mM N), 64% (10 mM N), 71% (15 mM N), and 138% (20 mM N). At this stage there was no significant differences between the four plants with N ranging from 6.69 (0 mM N) to 11.91 (15 mM N); an increase of 78% (Figure 6).

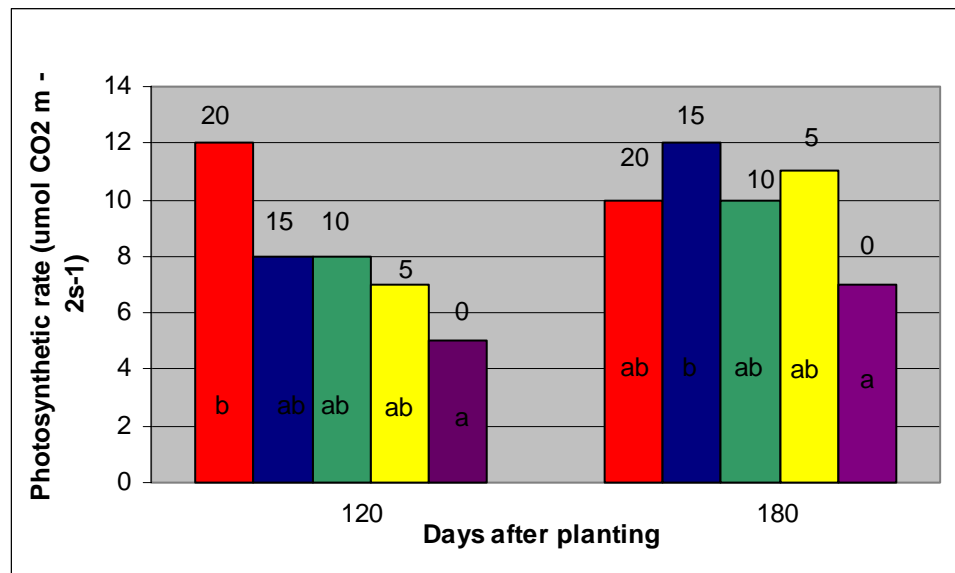


Figure 6. Photosynthetic rate of sugarcane US 67-22-2 in greenhouse experiment.

4.1.6 NUMBER OF LEAVES

In terms of number of leaves, at the three intervals there was no significant differences between the plants with nitrogen, while significant difference was found between the plant with no nitrogen and the rest of the plants with nitrogen. For instance, at 60 days after planting, the number of leaves ranged from six at 0 mM N to 10 at 20

mM N, while at 120 and 180 days after planting, it ranged from 11 to 16 and from 17 to 23 at 0 mM N and 20 mM N, respectively (Figure 7).

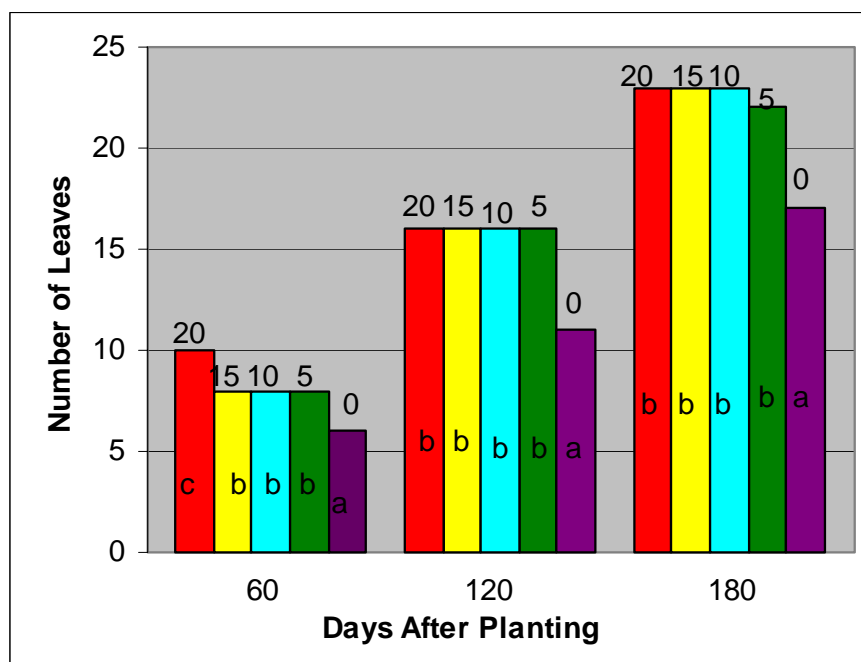


Figure 7. Number of green leaves of sugarcane US 67-22-2 in greenhouse experiment.

4.1.7 HARVEST

4.1.7.1 GREEN LEAVES (Fresh Weight)

When the experiment was harvested at 8 months after planting, it was observed that in terms of fresh weight of the green leaves, there was no significant differences between 0 and 5 mM N/L treatments, and the plants with the three highest nitrogen levels were significantly superior to 0 and 5 mM N levels. The highest value (300 g/plant) was obtained at 10 mM N treatment, an increase of 88% as compared to the control plants (Figure 8).

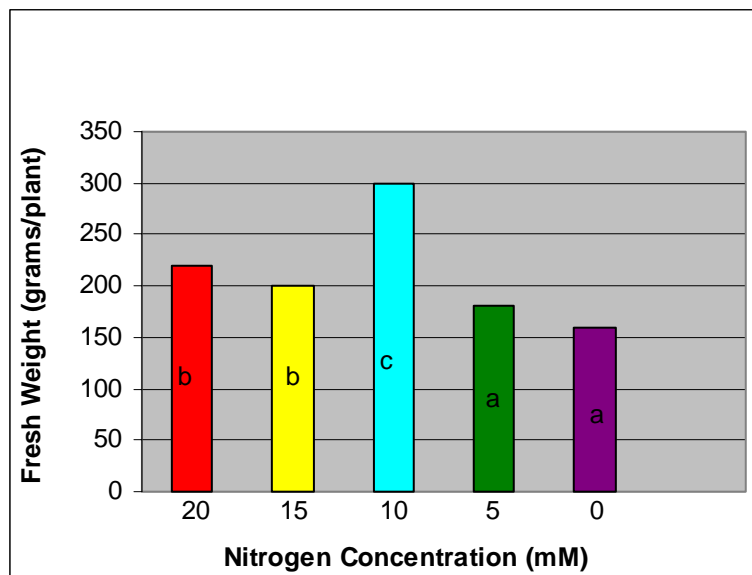


Figure 8. Green leaves (fresh weight) of sugarcane US 67-22-2 in greenhouse experiment.

4.1.7.2 GREEN LEAVES (Dry Weight)

The dry weight of the leaves was also taken and there was no significant difference between 0 and 5 mM N, and 10 and 20 mM N treatments. The dry weight ranged from 90 to 210 g/plant at 0 mM N and 10 mM N, respectively. The second highest value was observed at the 20 mM N treatment (200 g/plant), which was not significantly different from that of the 10 mM N treatment. It was demonstrated that with the application of 10 mM N the plants gained in average 12 g/unit of nitrogen (Figure 9).

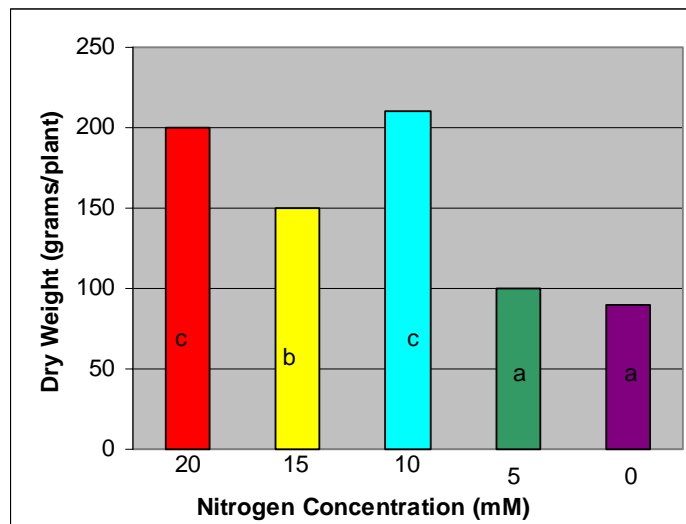


Figure 9. Green leaves (dry weight) of sugarcane US 67-22-2 in greenhouse experiment.

4.1.7.3 STEM (Fresh Weight)

When looking at the stem fresh weight, there was significant difference among all the treatments, with the highest value for the 20 mM N treatment. The stem fresh weight ranged from 200 to 3,800 g/plant at 0 mM N and 20 mM N, respectively. The largest increment in stem fresh weight was observed between 0 mM N and 5 mM N (Figure 10).

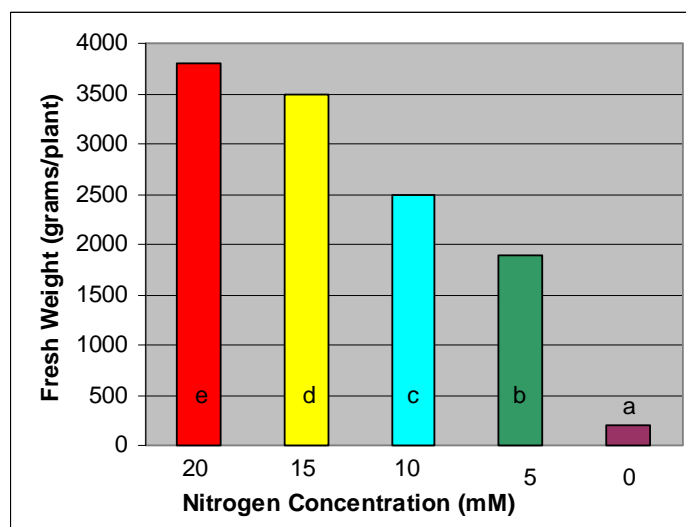


Figure 10. Stem (fresh weight) of sugarcane US 67-22-2 in greenhouse experiment.

4.1.7.4 STEM (Dry Weight)

Stem dry weight values increased 450% from 200 to 1,100 g/plant, at 0 mM N and 20 mM N, respectively. The second highest value was observed at the 15 mM N (1,000 g/plant), which was not significantly different from 10 mM N treatment (950 g/plant) (Figure 11).

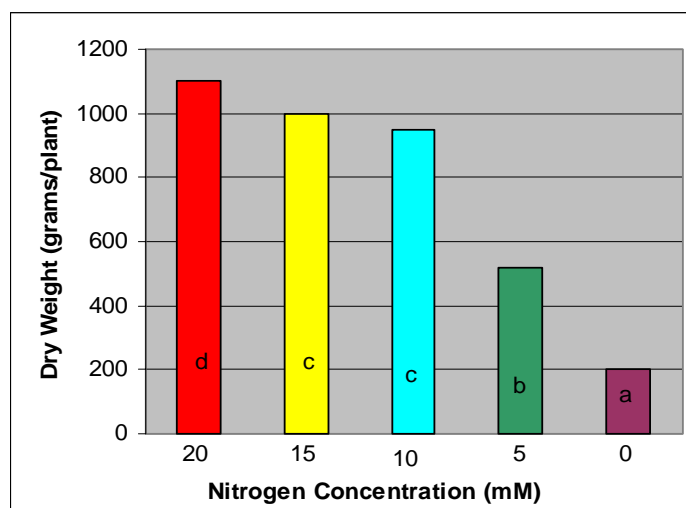


Figure 11. Stem (dry weight) of sugarcane US 67-22-2 in greenhouse experiment.

4.1.7.5 ROOT (Fresh and Dry Weight)

Roots fresh weight and dry weight the trends were similar. For instance, in terms of fresh weight it ranged from 300 to 4,000 g/plant at 0 mM N and 15 mM N, respectively. The second highest value was observed at the 20 mM N treatment (3,900 g/plant), which was not significantly different from the value of the highest nitrogen level studied (Figure 12).

In terms of roots dry weight the values ranged from 340 to 2,600, at 0 mM N and 20 mM N, respectively. The second highest value registered at 15 mM N treatment did not differ significantly from the highest value. It was demonstrated that with the application of 20 mM N, the plants gained in average 113 g of dry root/per unit of nitrogen (Figure 13).

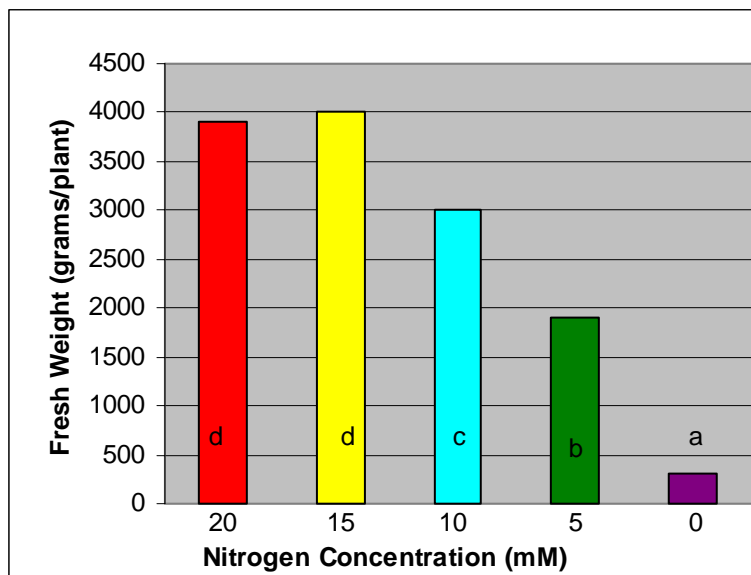


Figure 12. Root (fresh weight) of sugarcane US 67-22-2 in greenhouse experiment.

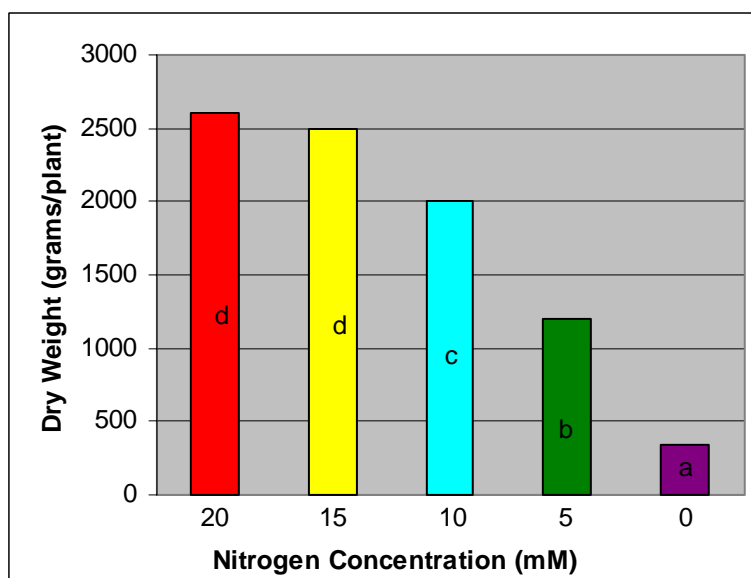


Figure 13. Root (dry weight) of sugarcane US 67-22-2 in greenhouse experiment.

4.1.8 CONCLUSIONS

1. In terms of leaf area, plant height and number of leaves; in general the plants with nitrogen were significantly superior to the control and statistically similar among them at the three growing intervals. The most dramatic increase occurred between 120 and 180 days.
2. The application of nitrogen increased the number of tillers in over 700%.
3. In terms of leaf relative chlorophyll content, the control showed 36% less than the average of the plants with nitrogen.
4. At 120 days after planting, photosynthetic rate increased 138% from 0 mM N to 20 mM N.
5. When looking at the harvest yield data (leaves, stem, and roots dry weight), in general there was a trend in which the highest significant values were obtained with the application of 20 mM N.

4.2 FIELD EXPERIMENT

4.2.1 HARVEST INTERVALS

4.2.1.1 GREEN MATTER YIELD

Figures 14, 15, and 16 show the regression analyses between nitrogen levels and green matter yield (GMY) of *Saccharum spontaneum* when harvested at 240, 270, and 300 days at Lajas, Puerto Rico, respectively. The GMY of sugarcane increased with increasing N rates and harvest interval (HI). At 240 day HI, the GMY increased from 13,182 Kg/ha at zero nitrogen, to 53,783 Kg/ha with 1344 Kg N/ha. The greatest increase, 252% was observed with the application of the first 448 Kg N/ha (Figure 14). A similar trend was observed at 270 and 300 day HI. At 270 day HI, the GMY increased 119% with the application of 448 Kg N/ha, from 24,634 (0 N) to 53,954 Kg/ha (448 N). The GMY from the 448 Kg N/ha level to the maximum level applied, increased by only 19% (Figure 15). At 300 day HI, the GMY increased 107% from 36,346 at zero N to 75,094 Kg/ha with the application of the first 448 Kg N/ha. However, the GMY from 448 Kg N/ha level to the maximum level applied, increased by only 43% (Figure 16).

The GMY observed at this experiment was slightly lower than those registered at other investigations. For instance, Hussain et al. (2003) observed a cane yield of 91,620 Kg/ha at 100:50 N:P level Kg/ha. Esanullah et al. (2001) found that 200 Kg N along with 150 Kg P₂O₅/ha resulted in the highest cane yield of 76,640 Kg/ha.

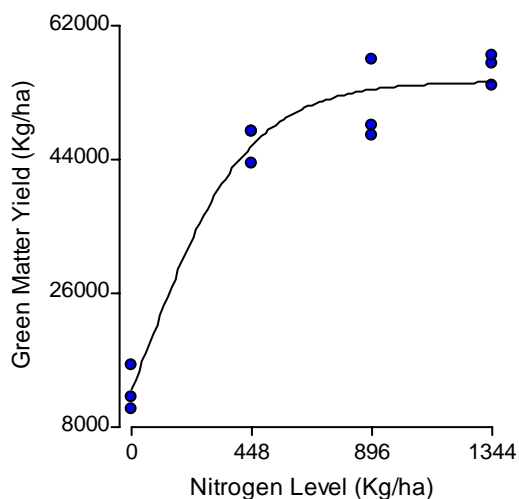


Figure 14. Green matter yield of sugarcane US 67-22-2 at 240 days after planting in Lajas, Puerto Rico as a function of nitrogen fertilization.

In terms of statistical analysis it was determined that a quadratic regression fitted the data adequately. The R^2 was 0.86.

Table 1. Quadratic Regression analysis for green matter yield of sugarcane US 67-22-2 at 240 days after planting in Lajas, Puerto Rico.

Model Green Forage Yield = $\text{alfa} \cdot \exp(-\text{beta} \cdot \exp(-\text{gamma} \cdot \text{Treatment})) + \text{delta}$

Variable	N	MSError	Interaction
Green Forage Yield	12	16339510.61	3

Parameters	Estimation	E.E.	T	p
ALFA	54468.40	178922.31	0.30	0.7686
BETA	1.43	10.26	0.14	0.8925
GAMMA	0.00	0.01	0.55	0.5991
DELTA	55.59	176442.07	0.00	0.9998

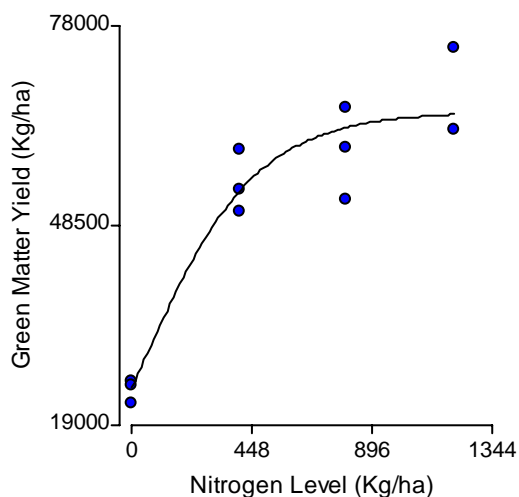


Figure 15. Green matter yield of sugarcane US 67-22-2 at 270 days after planting in Lajas, Puerto Rico as a function of nitrogen fertilization.

In terms of statistical analysis it was determined that a quadratic regression model fitted the data adequately. The R^2 was 0.79.

Table 2. Quadratic Regression analysis for green matter yield of sugarcane US 67-22-2 at 270 days after planting in Lajas, Puerto Rico.

Model Green Forage Yield = $\alpha \cdot \exp(-\beta \cdot \exp(-\gamma \cdot \text{Treatment})) + \delta$

Variable	N	MSError	Interaction
Green Forage Yield	11	41056230.75	3

Parameters	Estimation	E.E.	T	p
ALFA	55813.21	210292.63	0.27	0.7983
BETA	1.31	9.82	0.13	0.8974
GAMMA	0.00	0.01	0.45	0.6631
DELTA	9526.58	204146.91	0.05	0.9641

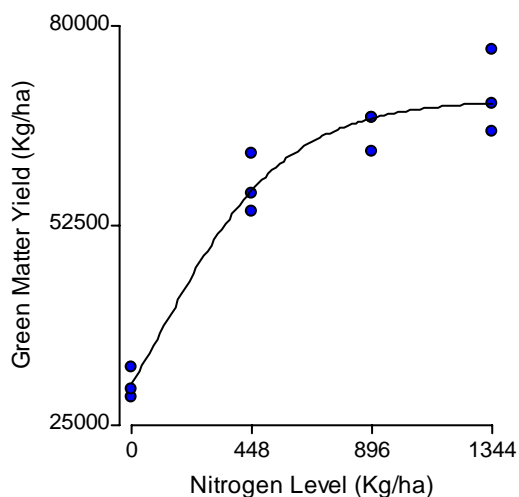


Figure 16. Green matter yield of sugarcane US 67-22-2 at 300 days after planting in Lajas, Puerto Rico as a function of nitrogen fertilization.

In terms of statistical analysis it was determined that a quadratic regression model fitted the data adequately. The R^2 was 0.98.

Table 3. Quadratic Regression analysis for green matter yield of sugarcane US 67-22-2 at 300 days after planting in Lajas, Puerto Rico.

Model Green Forage Yield = $\text{alfa} \cdot \exp(-\text{beta} \cdot \exp(-\text{gamma} \cdot \text{Treatment})) + \text{delta}$

Variable	N	MSError	Interaction
Green Forage Yield	12	16734653.97	3

Parameters	Estimation	E.E.	T	p
ALFA	48903.99	71760.83	0.68	0.5148
BETA	1.61	5.51	0.29	0.7779
GAMMA	0.00	0.00	0.85	0.4181
DELTA	21000.71	68515.06	0.31	0.7670

The data in Table 4 show the effect of nitrogen level and harvest interval on dry matter yield, dry matter content, plant height, number of tillers, number of leaves, and leaf area of *Saccharum spontaneum* at Lajas, Puerto Rico.

Table 4. Effect of nitrogen level and harvest interval on the dry matter content, dry matter yield, plant height, number of tillers, number of leaves, and leaf area of *Saccharum spontaneum* at 240, 270, and 300 day harvest intervals at Lajas, Puerto Rico¹.

N Level	Dry Matter Yield	Plant Height (Main Stem)	No. of Tillers	No. of Leaves per plant	Leaf Area per plant	No. of Leaves (main stem)	Leaf Area (main stem)
Kg/ha	Kg/ha	cm			cm ²		cm ²
240 day Harvest Interval							
0	4371 a	80 a	5 a	53 a	6085 a	10 a	1257 a
448	14855 b	142 b	9 b	111 b	28584 b	11 a	3041 b
896	16858 b	159 bc	10 bc	121 b	34959 b	12 b	3511 c
1344	19672 c	185 c	14 c	154 c	45329 b	13 b	4147 d
CV	9.2	14.1	16.8	8.1	33.3	6.64	3.33
270 day Harvest Interval							
0	7495 a	89 a	6 a	55 a	8860 a	11 a	1763 a
448	26021 b	157 b	9 ab	112 b	28895 b	11 a	3250 b
896	21975 b	172 bc	11 bc	127 b	38151bc	12 b	3899 c
1344	24826 b	199 c	14 c	157 c	47932 c	13 b	4348 c
CV	16.2	13.3	19.4	7.6	27.3	5.98	8.05
300 day Harvest Interval							
0	12600 a	103 a	6 a	57 a	8873 a	11 a	1700 a
448	25811 b	175 b	10 ab	121 b	44395 b	13 b	3867 b
896	26316 b	186 bc	12 b	137 b	49741 b	13 b	4633 c
1344	30411 b	217 c	14 b	169 c	54521 b	15 c	5240 c
CV	10.3	11.8	19.8	10.8	28.5	4.44	9.15

4.2.1.2 DRY MATTER YIELD

The Dry Matter Yield (DMY) of sugarcane increased with increasing N rates and HI. At 240- day HI, the mean DMY increased from 4,371, when no N was applied, to 19,672 Kg/ha with 1,344 Kg N/ha. The greatest increase (240%) was observed with the

¹ Within each column and harvest interval, means in columns follow by one or more letters in common do not differ significantly at P = 0.05, according to Duncan's multiple range test.

application of the first 448 Kg N/ha. However, the DMY from the 448 Kg N level to the maximum level applied, increased by only 32%. A similar trend was observed at 270- and 300- day HI. At 270- day HI, the mean DMY increased 231% with the application of 448 Kg N/ha, from 7,495 (0 N) to 24,826 Kg/ha (448 N). No significant differences were observed between the N treatments at 270 day HI. At 300-day HI, the mean DMY increased from 12,600 when no N was applied to 30,411 Kg/ha with the application of 1,344 Kg N/ha. Again, the greatest increase (105%) was observed with the application of the first 448 Kg N. No significant differences were observed between the nitrogen treatments. In general these yields were higher than those registered by Guindin-García in 2003. Based on this data it seems that it pays to reach the 300- day HI to reach an optimum GM and DMY (Table 4).

According to this yield data, the application of 448 Kg N/ha seems to be enough to obtain an adequate yield. Nevertheless, the world recommended rates of N fertilizer for sugarcane production vary between 45.6 and 304.3 Kg N/ha/yr (Srivastava and Suarez, 1992). By other hand, it is well documented in the literature that the response to nitrogen fertilization occurs more in ratoon crops than on plant cane crops (de Geus, 1973; Wood, 1964). The optimum rate of nitrogen fertilizer for sugarcane in many areas is between 100 and 200 Kg N/ha/yr (de Geus, 1973). In Louisiana, recommended N rates for plant cane crops are 90-135 Kg/ha for most areas, while ratoon crop nitrogen recommendations are 135-157 Kg N/ha/yr for all areas (Curtis and Loupe, 1975). In most areas of Australia, current recommended rates for nitrogen fertilizer are 120-150 Kg N/ha for the plant cane crop, and 160-200 Kg N/ha for successive plant cane crop and ratoon crops (Canegrowers, 2002). At Florida, the establishment of optimum nitrogen fertilization rates has been limited to a few studies. Gashco (1983) determined that the highest sugarcane yield were obtained at nitrogen rates of 224 and 448 Kg/ha, for plant cane and first ratoon crops, respectively. At Puerto Rico, Landrau and Samuels (1954), found that the use of nitrogen produced yield increases for all crops except the plant cane. Also, at Puerto Rico González-Vélez and Samuels (1962) found no significant response to nitrogen fertilizer on an organic soil with a nitrogen content of 1.65%. At 232 days after

planting, Guindin Garcia (2003) registered sugarcane dry matter yield of 1218, 1066, 1848, and 1450 Kg/ha at nitrogen levels of 0, 50, 100, and 150 Kg/ha respectively. At 294 days the dry matter yield observed was 1973, 3067, 2279, and 2870 Kg/ha at nitrogen levels 0, 50, 100, and 150 Kg/ha.

4.2.1.3 PLANT HEIGHT

In all HI, plant height increased sharply with N fertilization up to the maximum tested. At each HI the plant height observed at 0 N was significantly lower, than the ones observed when N was applied. A similar trend to that of GMY and DMY was observed, in which the greatest increase occurred with the application of 448 Kg N/ha. A 77%, 76%, and 70% increase was observed at the 448 Kg N/ha for 240, 270, and 300 days, respectively. At 300 day HI the sugarcane registered 217 cm at the maximum level tested, while a plant height of only 103 cm was observed when no N was applied (Table 4). This data is in agreement with the experiment of Samuels and Cibes (1963), in which the mean height of the varieties studied showed that the highest nitrogen rate treatments produced the tallest cane.

4.2.1.4 NUMBER OF TILLERS AND LEAVES

Tillering is a desirable characteristic in sugarcane growth. Poor tillering is associated with poor growth conditions which allow weeds to grow and raise production costs. By other hand, excessive tillering can give rise to thin cane stalks. In all HI, the number of tillers and number of leaves increased sharply with nitrogen fertilization up to the maximum tested. At 240 day HI, the number of tillers observed at 0 N was significantly lower than the ones observed when N was applied. In terms of number of leaves, at every HI the values observed at 0 N were significantly lower than the remaining ones (Table 4). Again, the data collected was in agreement with previous studies in which the highest number of tillers and leaves were produced under the highest nitrogen levels. The number of leaves of the plant main stem followed a similar trend to that observed in number of leaves per plant.

4.2.1.5 LEAF AREA

The association of leaf area (LA) with DMY was consistent, which indicates that this trait might become an important selection criterion for sugarcane improvement. At every HI the LA observed was significantly lower at 0 N. At 240- day HI, it increased from 6,085 cm² when no N was applied, to 28,584 cm² with 448 Kg N/ha; it continued increasing thereafter until 45,329 cm² at 1,344 Kg N/ha. At 270- day HI it increased from 8,860 cm² when no N was applied, to 28,895 cm² with the application of 448 Kg N/ha, increasing thereafter until 47,932 cm² at 1,344 Kg N/ha. At 300- day a similar trend was observed ranging from 8,873 cm² (0 N) to 54,521 cm² (1,344 N). The leaf area of the plant main stem expressed a similar trend to the one observed for leaf area per plant (Table 4).

4.2.1.6 CORRELATION COEFFICIENTS WITH YIELD COMPONENTS

The data in Table 5 show the Spearman Correlation Coefficients between dry matter yield and plant height, number of tillers, number of leaves, and leaf area of *Saccharum spontaneum* at 240, 270, and 300 day harvest interval at Lajas, Puerto Rico.

Table 5. Spearman correlation coefficients between plant Dry Matter Yield and plant height, number of tillers, number of leaves per plant, and leaf area per plant of *Saccharum spontaneum* at 240, 270, and 300 day harvest interval at Lajas, Puerto Rico.

	Plant Height (cm)	Number of Tillers	Number of Leaves	Leaf Area (cm ²)
DMY 240- day	0.93	0.88	0.92	0.87
DMY 270- day	0.63	0.62	0.60	0.54
DMY 300- day	0.54	0.73	0.57	0.83

Previous studies have shown that plant height, number of tillers, number of leaves, and leaf area are important traits in sugarcane highly associated with yield. This performance was also observed in this study based on the correlation coefficients obtained (Table 5).

4.2.1.7 DRY MATTER YIELD PARTINIONING

Table 6 shows the effect of nitrogen level and harvest interval on dry matter yield partitioning of *Saccharum spontaneum* at Lajas, Puerto Rico. The trend was similar at every HI, observing values that were significantly lower when no N was applied as compared with the three rates of N application. As expected, at every HI and every N level the stem dry matter yield was the highest value, while the leaf and leaf apex dry matter yields were very similar. At every HI the greatest increase was observed with the application of 448 Kg of N. For instance, at 240- day HI the dry matter yield increased 350, 198, and 425% for leaf apex, stem, and leaf, respectively with the application of 448 Kg/ha. As expected, the leaf stem ratio increased with the application of N. The average leaf stem ratio ranged from 0.15 (0 N) to 0.31 (1344 N), from 0.14 (0 N) to 0.20 (1344 N), and from 0.16 (0 N) to 0.21 (1344 N), for 240-, 270-, and 300- day HI, respectively. Obviously, nitrogen is required to obtain a higher proportion of leaves as compared to stem. In general, plants with higher leaf/stem ratio will register higher photosynthetic rates due to the larger amount of leaves.

Table 6. Effect of nitrogen level and harvest interval on dry matter yield partitioning *Saccharum spontaneum* at Lajas, Puerto Rico.¹

Dry matter yield partitioning				
N Level	Leaf apex	Stem	Leaf	Leaf/Stem Ratio
Kg/ha	Kg/ha	Kg/ha	Kg/ha	
240- DAY HARVEST INTERVAL				
0	448 a	3422 a	501 a	0.15
448	2015 b	10211 b	2629 b	0.25
896	2546 bc	11008 b	3304 bc	0.3
1344	2868 c	12800 c	4004 c	0.31
CV	14.7	9.4	23.2	
270- DAY HARVEST INTERVAL				
0	666 a	6012 a	817 a	0.14
448	2915 b	19890 b	3216 b	0.16
896	2374 b	16676 b	2925 b	0.18
1344	2918 b	18311 b	3596 b	0.2
CV	20.3	18.5	20	
300- DAY HARVEST INTERVAL				
0	987 a	10004 a	1609 a	0.16
448	2981 b	19161 b	3663 b	0.19
896	3286 bc	19136 b	3894 bc	0.2
1344	3748 c	22020 b	4644 c	0.21
CV	12.4	10.5	13.4	

¹ Within each column and harvest interval, means in columns followed by one or more letters in common do not differ significantly at P=0.05, according to Duncan's multiple range test.

4.2.1.8 PHYSIOLOGICAL RESPONSE

Table 7 shows the effect of nitrogen level and HI on photosynthetic rate and relative chlorophyll content of *Saccharum spontaneum* at Lajas, Puerto Rico. As expected, photosynthetic rate and relative chlorophyll content increased significantly with N applications. At 240 day HI, the photosynthetic rate and relative chlorophyll content at leaf number two increased from $6.5 \mu\text{mmol m}^2\text{s}^{-1} \text{CO}_2$ (0 N) to $17.33 \mu\text{mmol m}^2\text{s}^{-1} \text{CO}_2$ (1,344 N) and from 377 (0 N) to 807 (1,344 N), respectively. At leaf number seven, a similar trend was observed in which the photosynthetic rate and relative chlorophyll content increased from $4.5 \mu\text{mmol CO}_2$ (0 N) to $15.33 \mu\text{mmol m}^2\text{s}^{-1} \text{CO}_2$ (1,344 N) and from 337 (0 N) to 774 (1,344 N), respectively. At 270 day HI, the photosynthetic rate and relative chlorophyll content at leaf number 2 increased from $8 \mu\text{mmol m}^2\text{s}^{-1} \text{CO}_2$ (0 N) to $16.67 \mu\text{mmol m}^2\text{s}^{-1} \text{CO}_2$ (1,344 N) and from 361 (0 N) to 776 (1,344 N), respectively. At leaf number seven, a similar trend was observed in which the photosynthetic rate and relative chlorophyll content increased from $5.5 \mu\text{mmol m}^2\text{s}^{-1} \text{CO}_2$ (0 N) to $16.67 \mu\text{mmol m}^2\text{s}^{-1} \text{CO}_2$ (1,344 N) and from 316 (0 N) to 705 (1,344 N), respectively. At 300 day HI, the trend and values remained very similar. Interestingly, at every HI the greatest increase for both traits was observed with the application of the 448 Kg of N/ha. The data suggests that applications over 448 Kg N/ha are not required to obtain an adequate photosynthetic rate and relative chlorophyll content of the plant, which is in agreement with the yield response to N level.

Table 7. Effect of nitrogen level and harvest interval on photosynthetic rate and relative chlorophyll content at leaves number two and seven at Lajas, Puerto Rico ¹.

N Level	Photosynthetic Rate	Photosynthetic Rate	Relative Chlorophyll Content	Relative Chlorophyll Content
Kg/ha	$\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ Leaf #2	$\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ Leaf #7	Leaf #2	Leaf #7
240- DAY HARVEST INTERVAL				
0	6.5 a	4.5 a	377 a	337 a
448	14.0 b	11.67 b	621 b	589 b
896	15.67 bc	13.67 bc	730 c	673 bc
1344	17.33 c	15.33 c	807 c	774 c
CV	10	9.3	8.6	9.3
270- DAY HARVEST INTERVAL				
0	8 a	5.5 a	361 a	316 a
448	13 b	12.33 b	610 b	563 b
896	15.67 c	13.0 b	737 c	654 bc
1344	16.67 c	16.67 c	776 c	705 c
CV	6.3	12.1	9.4	10.2
300- DAY HARVEST INTERVAL				
0	6.5 a	4.0 a	363 a	328 a
448	12.67 b	10.67 b	673 b	622 b
896	15.67 c	14.67 c	757 bc	720 c
1344	17.33 d	16.0 c	810 c	760 c
CV	5.9	13.3	6.8	5.6

¹ Within each column and harvest interval, means in columns followed by one or more letters in common do not differ significantly at P=0.05, according to Duncan's multiple range test.

4.2.2 MONTHLY OBSERVATIONS

The data in Table 8 showed the effect of growth stage (days after planting) and nitrogen level on plant height, number of tillers, number of leaves, and leaf area of *Saccharum spontaneum* at Lajas, Puerto Rico. In general terms, all traits increased with increasing nitrogen rates up to the maximum level tested.

Table 8. Effect of growth stage and N levels on plant height, number of tillers, number of leaves, and leaf area of *Saccharum spontaneum* at Lajas, Puerto Rico ¹

DAP								
N level Kg/ha	90	120	150	180	210	240	270	300
PLANT HEIGHT (cm)								
0	36 a	46 a	59 a	69 a	76 a	80 a	89 a	103 a
448	57 b	78 b	106 b	120 b	133 b	142 b	157 b	175 b
896	69 c	89 bc	117 b	130 b	144 bc	159 bc	172 bc	186 bc
1344	71 c	97 c	132 b	150 b	167 c	185 c	199 c	217 c
CV	7.9	11.8	13.1	13.3	11.3	14.1	13.3	11.8
NUMBER OF TILLERS								
0	0.33 a	2 a	5 a	6 a	5 a	5 a	6 a	6 a
448	2 b	4 b	7 ab	9 b	9 b	9 b	9 ab	10 ab
896	3 c	6 bc	8 b	9 b	10 b	10 bc	11 bc	12 b
1344	3 c	7 c	11 c	13 c	14 c	14 c	14 c	14 b
CV	13.9	21.4	17.9	11.6	16.8	16.8	19.4	19.8
NUMBER OF LEAVES								
0	11 a	22 a	39 a	45 a	50 a	53 a	55 a	57 a
448	24 b	57 b	83 b	108 b	109 b	111 b	112 b	121 b
896	27 b	65 b	92 b	119 b	120 b	121 b	127 b	137 b
1344	32 b	79 b	107 c	144 c	144 c	154 c	157 c	169 c
CV	17.8	24.5	8.9	7.4	8.1	8.1	7.6	10.8
LEAF AREA (cm²)								
0	1433 a	2722 a	4736 a	5828 a	6020 a	6085 a	8860 a	8873 a
448	6565 b	16135 b	21973 b	27450 b	27481 b	28584 b	28895 b	44395 b
896	7945 c	17943 b	26188 bc	33467 b	33643 b	34959 b	38151 bc	49741 b
1344	9078 d	19856 b	30351 c	40986 b	43986 b	45329 b	47932 c	54521 b
CV	5.6	13.8	19.3	32.6	33.9	33.3	27.3	28.5

¹ Within each column and growth stage, means in columns followed by one or more letters in common do not differ significantly at P=0.05, according to Duncan's multiple range test.

Table 9. Effect of growth stage and N levels on number of leaves/main stem and main leaf area of *Saccharum spontaneum* at Lajas, Puerto Rico ¹.

DAP								
N level Kg/ha	90	120	150	180	210	240	270	300
Number of Leaves (Main Stem)								
0	6 a	8 a	8 a	9 a	10 a	10 a	11 a	11 a
448	8 b	8 ab	9 b	10 ab	10 a	11 a	11 a	13 b
896	8 bc	9 bc	9 b	10 b	10 a	12 b	12 b	13 b
1344	9 c	10 c	10 b	12 c	12 b	13 b	13 b	15 c
CV	7.45	6.47	6.3	7.97	8.83	6.64	5.98	4.44
Leaf Area (cm²) (Main Stem)								
0	816 a	1065 a	1083 a	1273 a	1257 a	1355 a	1763 a	1700 a
448	1966 b	2340 b	2481 b	2581 b	3041 b	3091 b	3250 b	3867 b
896	2195 c	2929 c	2967 c	3331 c	3502 c	3511 c	3899 c	4633 c
1344	2555 d	3059 c	3219 d	3684 d	3963 d	4147 d	4348 c	5240 c
CV	6.24	5.54	4.48	2.74	2.05	3.33	8.05	9.15

¹ Within each column and growth stage, means in columns followed by one or more letters in common do not differ significantly at P=0.05, according to Duncan's multiple range test.

4.2.2.1 PLANT HEIGHT

In terms of plant height it ranged from 36 cm at 90 days after planting (DAP) to 103 cm at 300 DAP when no N was applied, and from 71 cm at 90 DAP to 217 cm at 300 DAP at maximum level tested. Interestingly, at every growth stage the greatest increase (58 to 80%) was observed with the application of 448 Kg N/ha. Nevertheless, the increase observed from 448 to 1344 Kg N/ha was in a range of 19 to 30% which was non significant different. This parameter did not level out suggesting this that plants will continue growing after 300 days until a certain point in time (Figure 17 and Table 8).

In terms of degree days the sugarcane US 67-22-2 required 1500 degree days to reach a plant height of 38, 65, 76, and 81 cm at 0, 448, 896, and 1344 Kg N/ha, respectively. By other hand, 5000 degree days were required to reach a plant height of 101, 177, 191, and 223 cm at 0, 448, 896, and 1344 Kg N/ha, respectively (Figure 18).

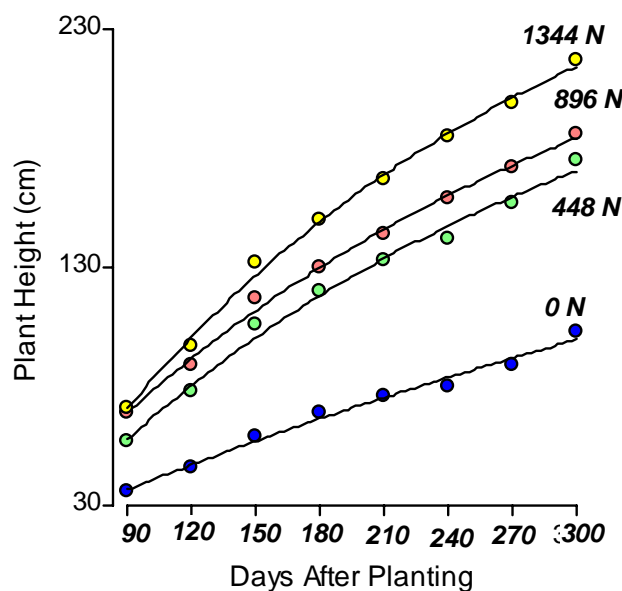


Figure 17. Plant height at four N levels and eight monthly intervals of sugarcane US 67-22-2 in Lajas, Puerto Rico.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.99, 0.99, 0.99, and 0.99 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 10. Quadratic regression analysis for plant height of sugarcane US 67-22-2 at different growth stages in Lajas, Puerto Rico.

$$\text{Model PH} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	PH	8	9.55	5

Parameters	Estimation	E.E.	T	p
ALFA	247.32	186.34	1.33	0.2418
BETA	0.99	0.04	25.14	<0.0001
GAMMA	0.17	0.18	0.95	0.3851

$$\text{Model PH} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	PH	8	19.97	2

Parameters	Estimation	E.E.	T	p
ALFA	252.26	46.21	5.46	0.0028
BETA	1.12	0.10	10.80	0.0001
GAMMA	0.41	0.15	2.81	0.0374

$$\text{Model PH} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	PH	8	8.47	5

Parameters	Estimation	E.E.	T	p
ALFA	276.56	34.23	8.08	0.0005
BETA	1.06	0.06	19.20	<0.0001
GAMMA	0.39	0.09	4.15	0.0089

$$\text{Model PH} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	PH	8	12.10	3

Parameters	Estimation	E.E.	T	P
ALFA	303.33	29.35	10.34	0.0001
BETA	1.16	0.07	16.32	<0.0001
GAMMA	0.46	0.09	5.09	0.0038

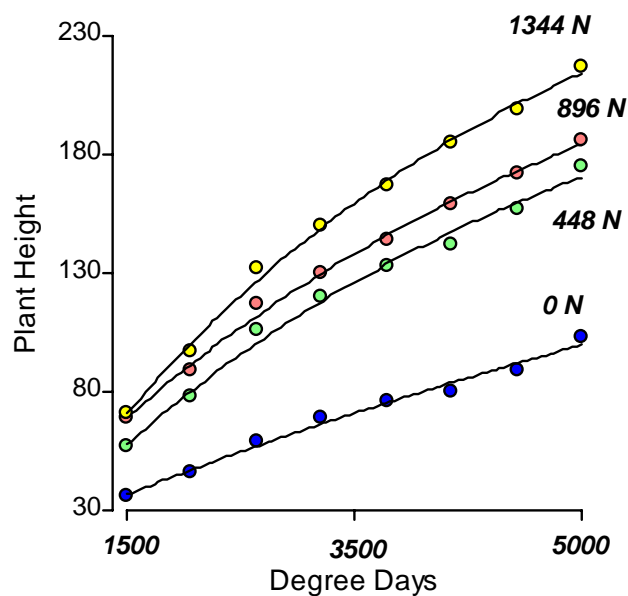


Figure 18. Plant height as a function of Degree Days and N fertilization of sugarcane US 67-22-2 in Lajas, Puerto Rico.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.99, 0.99, 0.99, and 0.99 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 11. Quadratic regression analysis for plant height of sugarcane US 67-22-2 as a function of Degree Days in Lajas, Puerto Rico.

$$\text{Model PH} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	PH	8	9.55	3

Parameters	Estimation	E.E.	T	p
ALFA	247.32	186.34	1.33	0.2418
BETA	0.99	0.04	25.14	<0.0001
GAMMA	0.10	0.11	0.95	0.3851

$$\text{Model PH} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	PH	8	19.97	4

Parameters	Estimation	E.E.	T	p
ALFA	252.26	46.21	5.46	0.0028
BETA	1.12	0.10	10.80	0.0001
GAMMA	0.25	0.09	2.81	0.0374

$$\text{Model PH} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	PH	8	8.47	5

Parameters	Estimación	E.E.	T	p
ALFA	276.56	34.23	8.08	0.0005
BETA	1.06	0.06	19.20	<0.0001
GAMMA	0.23	0.06	4.15	0.0089

$$\text{Model PH} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	PH	8	12.10	4

Parameters	Estimation	E.E.	T	p
ALFA	303.33	29.35	10.34	0.0001
BETA	1.16	0.07	16.32	<0.0001
GAMMA	0.27	0.05	5.09	0.0038

4.2.2.2 NUMBER OF TILLERS AND LEAVES

The number of tillers and number of leaves followed similar trends. For instance, the number of tillers ranged from 2 at 90 DAP to 7 at 300 DAP when no N was applied, and from 3 at 90 DAP to 14 at 300 DAP at maximum nitrogen level tested. The number of leaves ranged from 13 at 90 DAP to 53 at 300 DAP when no N was applied, and from 41 at 90 DAP to 156 at 300 DAP at maximum nitrogen level tested. Both traits showed significantly lower values when no N was applied, as compared with the remaining treatments. Nevertheless, there were no significant differences between the application of 448 and 896 Kg N/ha at all growth stages (Figures 19, 21, and Table 8). The number of leaves per stem followed a similar trend to that observed at the total number of leaves per plant (Table 9).

In terms of degree days the sugarcane US 67-22-2 required 1500 degree days to produce 0.22, 2, 4, and 3 tillers at 0, 448, 896, and 1344 Kg N/ha, respectively. By other hand, 5000 degree days were required to reach 6, 9, 11, and 14 tillers at 0, 448, 896, and 1344 Kg N/ha, respectively (Figure 20). The sugarcane US 67-22-2 required 1500 degree days to produce 13, 28, 32, and 41 leaves at 0, 448, 896, and 1344 Kg N/ha, respectively. By other hand, 5000 degree days were required to produce 52, 113, 126, and 156 leaves at 0, 448, 896, and 1344 Kg N/ha, respectively (Figure 22).

For number of leaves per stem the sugarcane required 1500 degree days to produce 6, 8, 8, and 9 leaves at 0, 448, 896, and 1344 Kg N/ha, respectively. Five thousand degree days were required to produce 11, 13, 13, and 15 leaves at 0, 448, 896, and 1344 Kg N/ha, respectively (Figure 24).

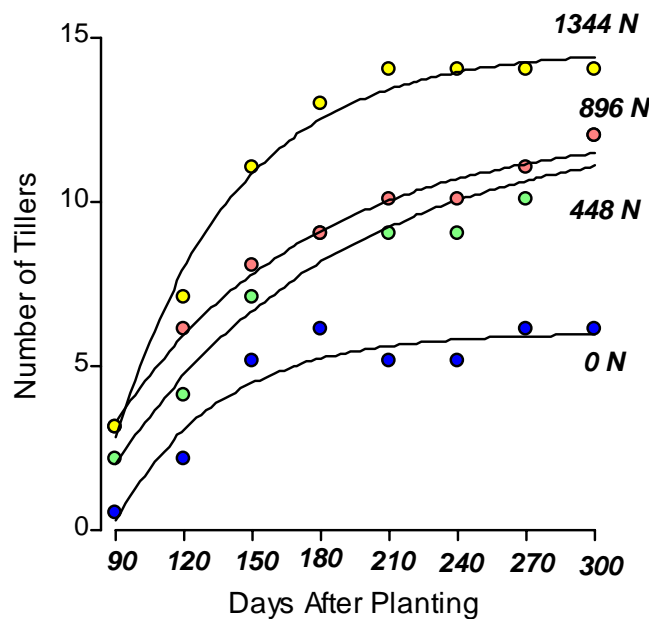


Figure 19. Number of tillers as a function of N fertilization of sugarcane US 67-22-2 in Lajas, Puerto Rico.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.90, 0.95, 0.98, and 0.98 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 12. Quadratic regression analysis for number of tillers of sugarcane US 67-22-2 at different growth stages in Lajas, Puerto Rico.

$$\text{Model \#T} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	#T	8	0.58	4

Parameters	Estimation	E.E.	T	p
ALFA	5.91	0.52	11.38	0.0001
BETA	7.16	5.61	1.28	0.2583
GAMMA	2.21	0.80	2.74	0.0406

$$\text{Model \#T} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	#T	8	0.73	7

Parameters	Estimation	E.E.	T	p
ALFA	12.32	1.70	7.26	0.0008
BETA	2.08	0.77	2.69	0.0432
GAMMA	1.00	0.39	2.59	0.0486

$$\text{Model \#T} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	INteraction
3.00	#T	8	0.18	5

Parameters	Estimation	E.E.	T	p
ALFA	12.24	0.64	18.99	<0.0001
BETA	2.12	0.44	4.86	0.0046
GAMMA	1.17	0.22	5.36	0.0030

$$\text{Model \#T} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	#T	8	0.35	3

Parameters	Estimation	E.E.	T	p
ALFA	14.64	0.47	31.31	<0.0001
BETA	4.56	1.22	3.72	0.0137
GAMMA	1.91	0.28	6.89	0.0010

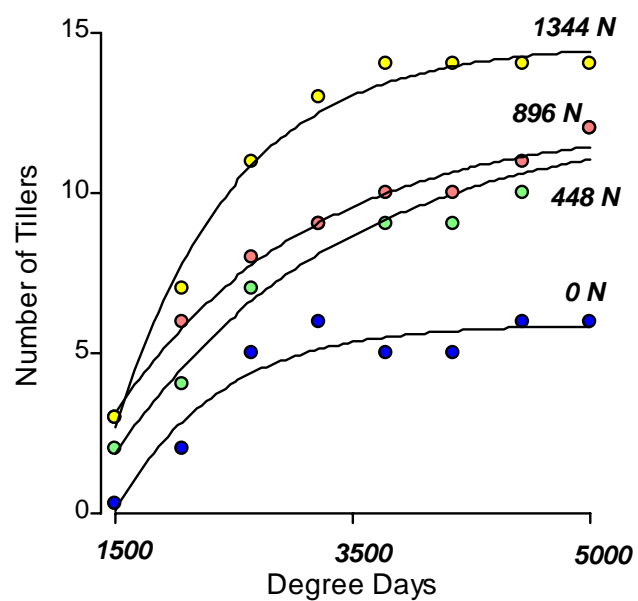


Figure 20. Number of tillers as a function of Degree Days and N fertilization.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.90, 0.95, 0.98, and 0.98 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 13. Quadratic regression analysis for number of tillers of sugarcane US 67-22-2 as a function of Degree Days and N fertilization in Lajas, Puerto Rico.

$$\text{Model \#T} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	#T	8	0.58	3

Parameters	Estimation	E.E.	T	p
ALFA	5.91	0.52	11.38	0.0001
BETA	7.16	5.61	1.28	0.2583
GAMMA	1.32	0.48	2.74	0.0406

$$\text{Model \#T} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	#T	8	0.73	3

Parameters	Estimation	E.E.	T	p
ALFA	12.32	1.70	7.26	0.0008
BETA	2.08	0.77	2.69	0.0432
GAMMA	0.60	0.23	2.59	0.0486

$$\text{Model \#T} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	#T	8	0.18	5

Parameters	Estimation	E.E.	T	p
ALFA	12.24	0.64	18.99	<0.0001
BETA	2.12	0.44	4.86	0.0046
GAMMA	0.70	0.13	5.36	0.0030

$$\text{Model \#T} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	#T	8	0.35	3

Parameters	Estimation	E.E.	T	p
ALFA	14.64	0.47	31.31	<0.0001
BETA	4.56	1.22	3.72	0.0137
GAMMA	1.15	0.17	6.89	0.0010

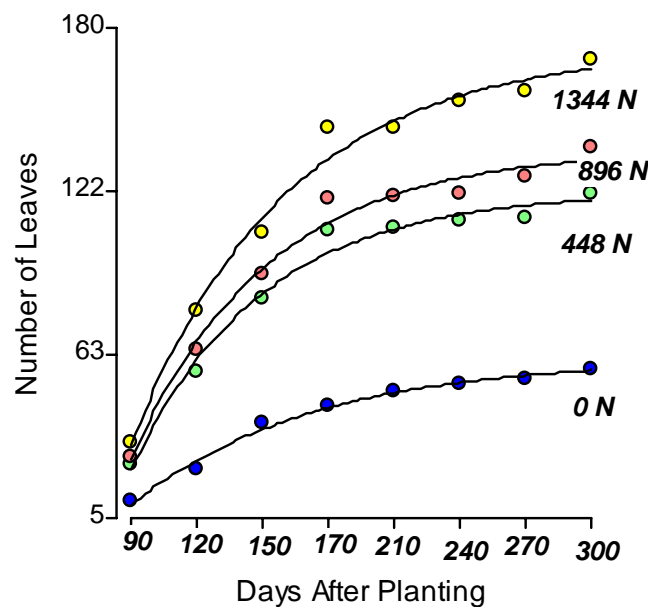


Figure 21. Number of leaves at four N levels and eight monthly intervals of sugarcane US 67-22-2.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.98, 0.98, 0.98, and 0.98 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 14. Quadratic regression analysis for number of leaves of sugarcane US
67-22-2 at different growth stages in Lajas, Puerto Rico.

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	\#L	8	4.37	3

Parameters	Estimation	E.E.	T	p
ALFA	61.75	3.02	20.46	<0.0001
BETA	2.51	0.47	5.37	0.0030
GAMMA	1.21	0.19	6.36	0.0014

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	\#L	8	26.72	2

Parameters	Estimation	E.E.	T	p
ALFA	121.46	4.74	25.62	<0.0001
BETA	3.70	0.98	3.77	0.0130
GAMMA	1.68	0.27	6.17	0.0016

$$\text{Modelo \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	\#L	8	30.12	3

Parameters	Estimation	E.E.	T	p
ALFA	136.56	5.35	25.53	<0.0001
BETA	3.42	0.84	4.05	0.0098
GAMMA	1.60	0.25	6.30	0.0015

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	\#L	8	38.43	3

Parameters	Estimation	E.E.	T	p
ALFA	172.43	7.08	24.37	<0.0001
BETA	2.95	0.62	4.76	0.0051
GAMMA	1.42	0.22	6.60	0.0012

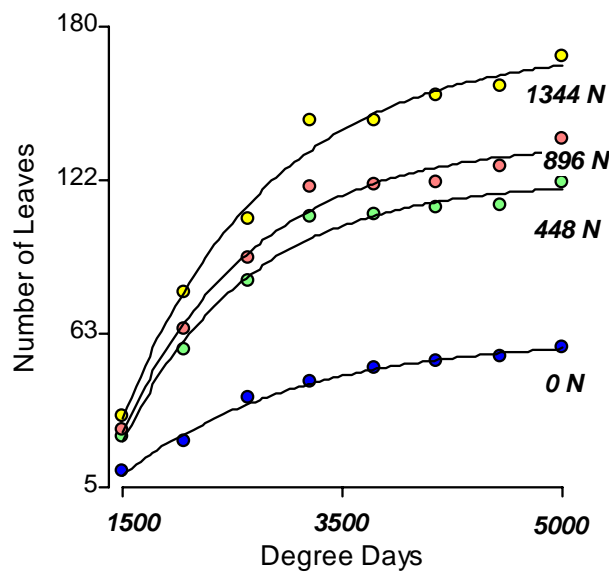


Figure 22. Number of leaves as a function of Degree Days and N fertilization.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.98, 0.98, 0.98, and 0.98 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 15. Quadratic regression analysis for number of leaves of sugarcane US 67-22-2 as a function of Degree Days and N fertilization in Lajas, Puerto Rico.

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	#L	8	4.37	3

Parameters	Estimation	E.E.	T	p
ALFA	61.75	3.02	20.46	<0.0001
BETA	2.51	0.47	5.37	0.0030
GAMMA	1.21	0.19	6.36	0.0014

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	#L	8	26.72	2

Parameters	Estimation	E.E.	T	p
ALFA	121.46	4.74	25.62	<0.0001
BETA	3.70	0.98	3.77	0.0130
GAMMA	1.68	0.27	6.17	0.0016

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	#L	8	30.12	3

Parameters	Estimation	E.E.	T	p
ALFA	136.56	5.35	25.53	<0.0001
BETA	3.42	0.84	4.05	0.0098
GAMMA	1.60	0.25	6.30	0.0015

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	#L	8	38.43	3

Parameters	Estimation	E.E.	T	p
ALFA	172.43	7.08	24.37	<0.0001
BETA	2.95	0.62	4.76	0.0051
GAMMA	1.42	0.22	6.60	0.0012

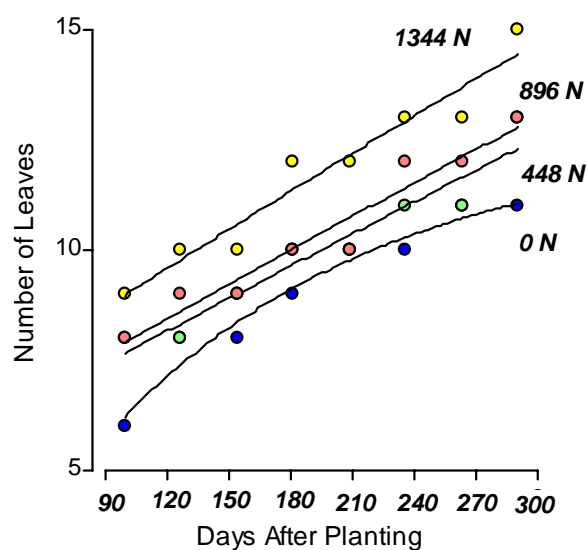


Figure 23. Number of leaves of main stem at four N levels and eight monthly intervals of sugarcane US 67-22-2.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.96, 0.93, 0.94, and 0.94 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 16. Quadratic regression analysis for number of leaves of the main stem of sugarcane US 67-22-2 at different growth stages in Lajas, Puerto Rico.

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	#L	8	0.16	3

Parameters	Estimation	E.E.	T	p
ALFA	12.58	1.55	8.12	0.0005
BETA	0.93	0.19	4.83	0.0048
GAMMA	0.68	0.31	2.18	0.0812

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	#L	8	0.27	2

Parameters	Estimation	E.E.	T	p
ALFA	108.20	1753.03	0.06	0.9532
BETA	0.95	0.82	1.15	0.3011
GAMMA	0.02	0.40	0.06	0.9575

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	#L	8	0.24	2

Parameters	Estimation	E.E.	T	p
ALFA	91.94	1017.50	0.09	0.9315
BETA	0.94	0.67	1.40	0.2209
GAMMA	0.03	0.36	0.08	0.9392

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	#L	8	0.32	2

Parameters	Estimation	E.E.	T	p
ALFA	78.44	628.82	0.12	0.9056
BETA	0.92	0.64	1.43	0.2112
GAMMA	0.04	0.37	0.11	0.9197

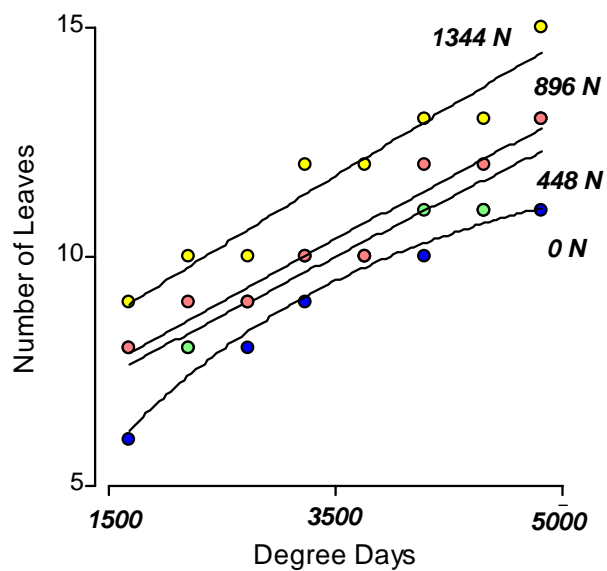


Figure 24. Number of leaves of the main stem as a function of Degree Days and N fertilization.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.96, 0.93, 0.94, and 0.94 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 17. Quadratic regression analysis for number of leaves of the main stem of sugarcane US 67-22-2 as a function of Degree Days and N fertilization in Lajas Puerto Rico.

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	#L	8	0.16	4

Parameters	Estimation	E.E.	T	p
ALFA	12.58	1.55	8.12	0.0005
BETA	0.93	0.19	4.83	0.0048
GAMMA	0.41	0.19	2.18	0.0812

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	#L	8	0.27	2

Parameters	Estimation	E.E.	T	p
ALFA	95.27	1324.58	0.07	0.9455
BETA	0.94	0.80	1.18	0.2910
GAMMA	0.02	0.24	0.06	0.9512

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	#L	8	0.24	2

Parameters	Estimation	E.E.	T	p
ALFA	97.29	1153.82	0.08	0.9361
BETA	0.94	0.68	1.38	0.2257
GAMMA	0.02	0.21	0.08	0.9429

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	#L	8	0.32	2

Parameters	Estimation	E.E.	T	p
ALFA	81.20	681.63	0.12	0.9098
BETA	0.92	0.65	1.42	0.2156
GAMMA	0.02	0.22	0.10	0.9228

4.2.2.3 LEAF AREA

Leaf area was significantly lower when no N was applied at every growth stage. In general, it ranged from 1,433 cm² at 90 DAP to 8,873 cm² at 300 DAP when no N was applied and from 9,078 cm² at 90 DAP to 54,521 cm² at 300 days after planting maximum level tested. At every growth stage the greatest increase was observed with the application of 448 Kg N/ha, while increases in the range of 23 to 66% were observed with the application of the maximum level tested as compared with the application of 448 Kg N/ha (Figure 25, Table 8).

The main stem leaf area followed a linear trend at every nitrogen level. The application of 448 Kg N/ha produced the highest increase (Figure 27, Table 9).

In terms of degree days the sugarcane US 67-22-2 required 1500 degree days to produce a leaf area of 2230, 13410, 8094, and 7016 cm² at 0, 448, 896, and 1344 Kg N/ha, respectively. By other hand 5000 degree days were required to produce a leaf area of 7602, 38753, 38699, and 48421 at 0, 448, 896, and 1344 Kg N/ha, respectively (Figure 26). In terms of main stem leaf area, the US 67-22-2 required 1500 degree days to produce a leaf area of 816, 1966, 2195, and 2555 cm² at 0, 448, 896, and 1,344 Kg N/ha, respectively. By other hand, 5000 degree days were required to produce a main stem leaf area of 1700, 3867, 4633, and 5240 cm² at 0, 448, 896, and 1,344 Kg N/ha, respectively (Figure 28).

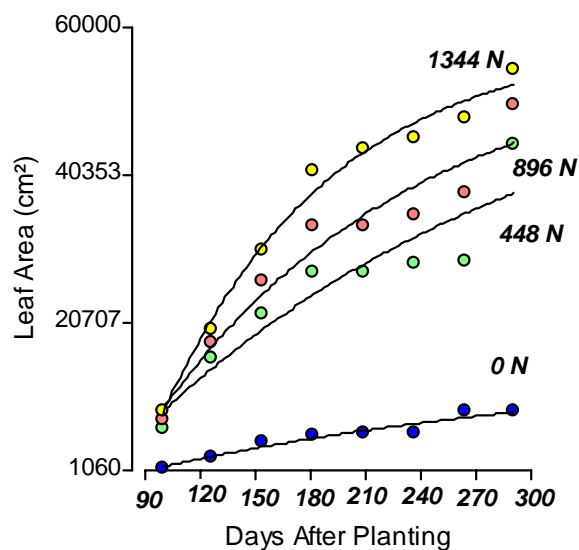


Figure 25. Leaf area at four N levels and eight monthly intervals of sugarcane US 67-22-2 in Lajas, Puerto Rico.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.94, 0.86, 0.93, and 0.98 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 18. Quadratic regression analysis for leaf area of sugarcane US 67-22-2 at different growth stages in Lajas, Puerto Rico.

$$\text{Model LA} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	LA	8	538453.85	2

Parameters	Estimation	E.E.	T	p
ALFA	15515.39	10387.31	1.49	0.1955
BETA	1.23	0.36	3.45	0.0182
GAMMA	0.35	0.37	0.95	0.3854

$$\text{Model LA} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	CMError	Interaction
2.00	LA	8	22910065.34	3

Parameters	Estimation	E.E.	T	p
ALFA	59462.23	50308.28	1.18	0.2904
BETA	1.23	0.56	2.19	0.0798
GAMMA	0.41	0.61	0.68	0.5296

$$\text{Model LA} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	LA	8	14463310.53	2

Parameters	Estimation	E.E.	T	p
ALFA	56709.22	16270.43	3.49	0.0176
BETA	1.51	0.55	2.75	0.0401
GAMMA	0.65	0.41	1.59	0.1723

$$\text{Model LA} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	LA	8	5105924.93	5

Parameters	Estimation	E.E.	T	p
ALFA	58691.26	4581.54	12.81	0.0001
BETA	2.08	0.43	4.89	0.0045
GAMMA	0.99	0.21	4.66	0.0055

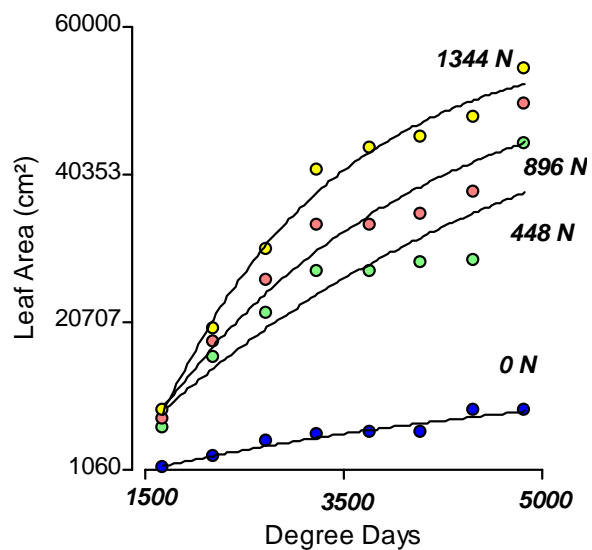


Figure 26. Leaf area as a function of Degree Days and N fertilization of sugarcane US 67-22-2 at Lajas, Puerto Rico.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.94, 0.86, 0.93, and 0.98 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 19. Quadratic regression analysis for leaf area of sugarcane US 67-22-2 as a function of Degreee Days and N fertilization in Lajas, Puerto Rico.

$$\text{Model LA} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	LA	8	538453.85	2

	Parameters	Estimation	E.E.	T	p
ALFA		15515.23	10386.96	1.49	0.1955
BETA		1.23	0.36	3.45	0.0182
GAMMA		0.21	0.22	0.95	0.3854

$$\text{Model LA} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	LA	8	22910065.34	3

	Parameters	Estimation	E.E.	T	p
ALFA		59461.50	50309.31	1.18	0.2904
BETA		1.23	0.56	2.19	0.0798
GAMMA		0.25	0.36	0.68	0.5296

$$\text{Model LA} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	LA	8	14463310.53	2

	Parameters	Estimation	E.E.	T	p
ALFA		56708.98	16270.33	3.49	0.0176
BETA		1.51	0.55	2.75	0.0401
GAMMA		0.39	0.25	1.59	0.1723

$$\text{Model LA} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	LA	8	5105924.93	2

	Parameters	Estimation	E.E.	T	p
ALFA		58691.25	4581.52	12.81	0.0001
BETA		2.08	0.43	4.89	0.0045
GAMMA		0.59	0.13	4.66	0.0055

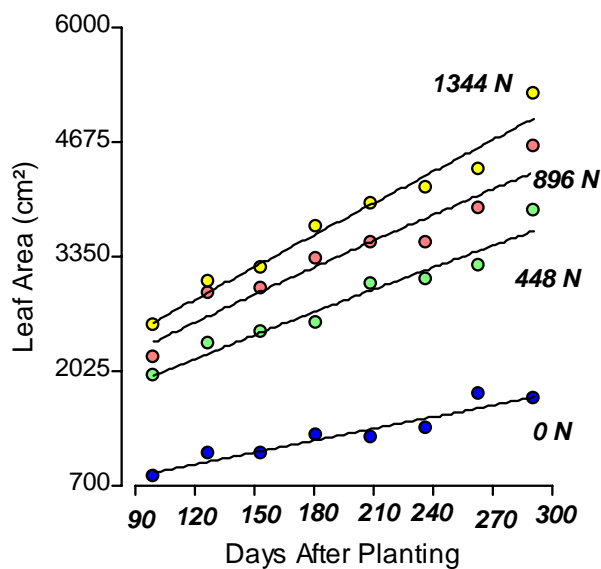


Figure 27. Leaf area of main stem at four N levels and eight monthly intervals of sugarcane US 67-22-2 at Lajas, Puerto Rico.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.86, 0.93, 0.91, and 0.95 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 20. Quadratic regression analysis for leaf area of the main stem of sugarcane US 67-22-2 at different growth stages in Lajas, Puerto Rico.

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	\#L	8	19473.91	2

Parameters	Estimation	E.E.	T	p
ALFA	22008.00	601872.65	0.04	0.9722
BETA	0.98	0.53	1.86	0.1217
GAMMA	0.02	0.58	0.03	0.9738

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	\#L	8	30752.88	2

Parameters	Estimation	E.E.	T	p
ALFA	32425.30	398891.64	0.08	0.9384
BETA	0.96	0.43	2.26	0.0732
GAMMA	0.03	0.37	0.07	0.9437

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	\#L	8	59624.22	2

Parameters	Estimation	E.E.	T	p
ALFA	28206.46	284989.64	0.10	0.9250
BETA	0.95	0.48	1.96	0.1072
GAMMA	0.04	0.44	0.09	0.9339

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	\#L	8	46137.58	2

Parameters	Estimation	E.E.	T	p
ALFA	41164.05	401450.19	0.10	0.9223
BETA	0.96	0.33	2.89	0.0343
GAMMA	0.03	0.33	0.09	0.9294

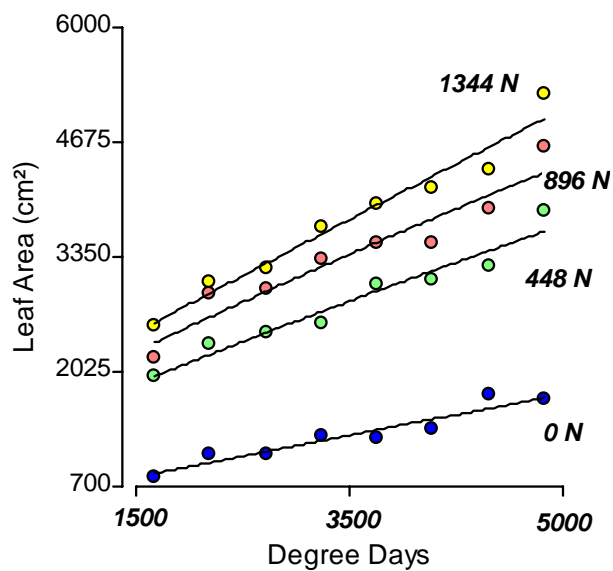


Figure 28. Leaf area of the main stem as a function of Degree Days and N fertilization.

In terms of statistical analysis it was determined that a negative exponential model fitted the data adequately. The R^2 were 0.86, 0.93, 0.91, and 0.95 for 0, 448, 896, and 1,344 Kg N/ha, respectively.

Table 21. Quadratic regression analysis for leaf area of the main stem of sugarcane US 67-22-2 as a function of degree days and N fertilization in Lajas, Puerto Rico.

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
1.00	#L	8	19511.57	2

	Parameters	Estimation	E.E.	T	p
ALFA		18755.30	428963.20	0.04	0.9668
BETA		0.98	0.51	1.92	0.1136
GAMMA		0.01	0.35	0.04	0.9690

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
2.00	#L	8	30724.51	2

	Parameters	Estimation	E.E.	T	p
ALFA		33233.43	420766.27	0.08	0.9401
BETA		0.96	0.43	2.25	0.0742
GAMMA		0.02	0.22	0.07	0.9451

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
3.00	#L	8	59655.54	2

	Parameters	Estimation	E.E.	T	p
ALFA		27646.04	272570.14	0.10	0.9232
BETA		0.95	0.48	1.97	0.1056
GAMMA		0.02	0.26	0.09	0.9324

$$\text{Model \#L} = \text{alfa} * (1 - \text{beta} * \exp(-\text{gamma} * x))$$

N	Variable	N	MSError	Interaction
4.00	#L	8	46187.96	2

	Parameters	Estimation	E.E.	T	p
ALFA		40124.42	379364.04	0.11	0.9199
BETA		0.96	0.33	2.91	0.0335
GAMMA		0.02	0.19	0.10	0.9273

4.2.2.4 PHYSIOLOGICAL RESPONSE

Table 22 shows the effect of growth stage and N levels on photosynthetic rate and relative chlorophyll content of *Saccharum spontaneum* at Lajas, Puerto Rico. As expected, photosynthetic rate and relative chlorophyll content increased significantly with N applications, although the growth stage apparently had no significant effect. At 120 DAP, the photosynthetic rate and relative chlorophyll content at leaf # 2 increased 100 % from 0 N Kg/ha to 1,344 N Kg/ha, and 94% from 0 N Kg/ha to 1,344 N Kg/ha, respectively. At leaf # 7 a similar trend was observed. At 210 DAP the photosynthetic rate and relative chlorophyll content of leaf # 2 increased 167% from 0 N Kg/ha to 1,344 N Kg/ha, and 141% from 0 N Kg/ha to 1,344 N Kg/ha, respectively. At leaf #7, a similar trend was observed in which the photosynthetic rate and relative chlorophyll content increased from 3.67 (0 N) to 14 $\mu\text{mol m}^{-2} \text{s}^{-1} \text{CO}_2$ (1,344 N) and from 296 (0 N) to 754 (1,344 N), respectively. In general, there was no significant differences between the N levels 448, 896, and 1,344 Kg N/ha, which suggests that applications over 448 Kg are not required to obtain adequate photosynthetic rate and relative chlorophyll content.

Table 22. Effect of growth stage and N levels on photosynthetic rate and relative chlorophyll content of *Saccharum spontaneum* at Lajas, Puerto Rico¹.

N level Kg/ha	DAP						
	120	150	180	210	240	270	300
PHOTOSYNTHETIC RATE ($\mu\text{mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) LEAF #2							
0	8.67 a	5.0 a	5.50 a	6.5 a	6.5 a	8 a	6.5 a
448	11.00 b	12.67 b	13.33 b	14.33 b	14.0 b	13 b	12.67 b
896	14.00 c	16.33 c	15.33 bc	15.33 b	15.67 bc	15.67 c	15.67 c
1344	17.33 d	17.33 c	16.67 c	17.33 c	17.33 c	16.67 c	17.33 d
CV	6.4	10.44	11.49	6.88	10	6.3	5.9
PHOTOSYNTHETIC RATE ($\mu\text{mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$) LEAF #7							
0	7.00 a	5.67 a	6.50 a	3.67 a	4.5 a	5.5 a	4.0 a
448	11.50 b	12.00 b	10.67 b	11.67 b	11.67 b	12.33 b	10.67 b
896	13.33 b	16.67 c	11.67 bc	12.33 b	13.67 bc	13.0 b	14.67 c
1344	18.00 c	16.0 c	12.33 c	14.00 c	15.33 c	16.67 c	16.0 c
CV	7.08	12.35	5.62	6.79	9.3	12.1	13.3
RELATIVE CHLOROPHYLL CONTENT LEAF #2							
0	337 a	443 a	365 a	332 a	377 a	361 a	363 a
448	453 ab	594 ab	575 b	559 b	621 b	610 b	673 b
896	534 bc	769 c	710 c	685 c	730 c	737 c	757 bc
1344	653 c	679 bc	759 c	801 d	807 c	776 c	810 c
CV	16.68	14.08	9.49	9.19	8.6	9.4	6.8
RELATIVE CHLOROPHYLL CONTENT #7							
0	330 a	409 a	344 a	296 a	337 a	316 a	328 a
448	440 ab	571 b	525 b	511 b	589 b	563 b	622 b
896	511 b	708 c	677 c	637 c	673 bc	654 bc	720 c
1344	647 c	691 c	718 c	754 d	774 c	705 c	760 c
CV	12.31	9.77	9.77	6.92	9.3	10.2	5.6

¹ Within each column and growth stage, means in columns followed by one or more letters in common do not differ significantly at P=0.05, according to Duncan's multiple range test.

4.2.2.5 CONCLUSIONS

1. Data obtained at the greenhouse demonstrated that to apply nitrogen at rates ranging from 10 to 20 mmol/L N, 1:10 (NH₄NO₃) pays dividends in terms of significantly superior yields. This trend was confirmed during the field experiment.
2. According to field data obtained and from the economical standpoint, the application of 448 Kg N/ha is enough to obtain an adequate plant cane yield at a reasonable cost.
3. Based on field data obtained, it seems that it pays to reach the 300 day harvest interval to get an optimum yield.
4. The association of plant height, number of tillers, number of leaves, and leaf area with yield was consistent, which indicates that these traits might become important selection criteria for sugarcane improvement.
5. Applications over 448 Kg N/ha are not required to obtain an adequate photosynthetic rate and relative chlorophyll content of the plant, which was in agreement with the yield response to nitrogen level.
6. Growth stage had no significant effect in the response of photosynthetic rate and relative chlorophyll content to nitrogen application.
7. Considering that this study only evaluated the plant cane response to nitrogen levels a further test is suggested to study the ratoon response to these same nitrogen levels.
8. Under climatological and edaphological conditions similar to the ones of the experimental site, the response of sugarcane to nitrogen levels and harvest intervals might be similar to the one observed at this experiment.

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APPENDICES

Appendix A

Statistical analyses for the open wall greenhouse experiment

Leaf Area 1:

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Area	20	0.73	0.65	24.63

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1983906.32	4	495976.58	9.93	0.0004
Treatment	1983906.32	4	495976.58	9.93	0.0004
Error	749535.83	15	49969.06		
Total	2733442.15	19			

Test : LSD Fisher Alfa: 0.05 DMS: 336.90737

Error: 49969.0553 gl: 15

Treatment	Medias	n	
0.00	307.50	4	A
5.00	875.07	4	B
10.00	1094.90	4	B
20.00	1110.93	4	B
15.00	1149.20	4	B

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf Area 2:

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Area	20	0.86	0.83	14.99

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	10755237.20	4	2688809.30	23.45	<0.0001
Treatment	10755237.20	4	2688809.30	23.45	<0.0001
Error	1720020.00	15	114668.00		
Total	12475257.20	19			

Test : LSD Fisher Alfa: 0.05 DMS: 510.36521

Error: 114668.0000 gl: 15

Treatment	Medias	n	
0.00	1011.00	4	A
5.00	1912.50	4	B
10.00	2493.00	4	C
20.00	2818.00	4	C D
15.00	3061.50	4	D

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf Area 3:

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Area	20	0.28	0.09	36.82

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	37825534.70	4	9456383.68	1.49	0.2555
Treatment	37825534.70	4	9456383.68	1.49	0.2555
Error	95353485.50	15	6356899.03		
Total	133179020.20	19			

Test : LSD Fisher Alfa: 0.05 DMS: 3799.99129

Error: 6356899.0333 gl: 15

Treatment	Medias	n		
0.00	5064.00	4	A	
15.00	6202.00	4	A	B
5.00	6758.00	4	A	B
10.00	6948.25	4	A	B
20.00	9264.25	4		B

Letras distintas indican diferencias significativas($p < 0.05$)

Height: Data set 1

ANOVA

Variable	N	R ²	R ² Aj	CV
Height	20	0.74	0.67	19.39

(SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Model	775.30	4	193.83	10.75	0.0003
Treatment	775.30	4	193.83	10.75	0.0003
Error	270.50	15	18.03		
Total	1045.80	19			

Test : LSD Fisher Alfa: 0.05 DMS: 6.40026

Error: 18.0333 gl: 15

Treatment	Medias	n		
0.00	9.50	4	A	
5.00	24.00	4		B
20.00	25.00	4		B
10.00	25.25	4		B
15.00	25.75	4		B

Letras distintas indican diferencias significativas($p < 0.05$)

Height: Data set 2

ANOVA

Variable	N	R ²	R ² Aj	CV
Height	20	0.80	0.75	11.92

(SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Model	9117.70	4	2279.43	14.96	<0.0001
Treatment	9117.70	4	2279.43	14.96	<0.0001
Error	2285.25	15	152.35		
Total	11402.95	19			

Test : LSD Fisher Alfa: 0.05 DMS: 18.60292

Error: 152.3500 gl: 15

Treatment	Medias	n		
0.00	61.75	4	A	
20.00	107.50	4		B
15.00	113.25	4		B

5.00	114.00	4	B
10.00	121.25	4	B

Letras distintas indican diferencias significativas($p < 0.05$)

Height: Data set 3

ANOVA

Variable	N	R ²	R ² Aj	CV
Height	20	0.88	0.85	7.74

(SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	56998.70	4	14249.68	28.82	<0.0001
Treatment	56998.70	4	14249.68	28.82	<0.0001
Error	7417.50	15	494.50		
Total	64416.20	19			

Test : LSD Fisher Alfa: 0.05 DMS: 33.51530

Error: 494.5000 gl: 15

Treatment	Medias	n	
0.00	182.50	4	A
20.00	294.00	4	B
15.00	317.50	4	B
5.00	319.75	4	B
10.00	322.75	4	B

Letras distintas indican diferencias significativas($p < 0.05$)

Chlorophyll 1:

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Chlorophyll	71	0.32	0.28	18.16

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	53385.76	4	13346.44	7.68	<0.0001
Treatment	53385.76	4	13346.44	7.68	<0.0001
Error	114661.87	66	1737.30		
Total	168047.63	70			

Test : LSD Fisher Alfa: 0.05 DMS: 31.45502

Error: 1737.3010 gl: 66

Treatment	Medias	n	
0.00	176.21	15	A
5.00	211.47	14	B
10.00	235.01	16	B C
20.00	250.36	10	C
15.00	259.71	16	C

Letras distintas indican diferencias significativas($p < 0.05$)

Chlorophyll 2:

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Chlorophyll	72	0.21	0.16	22.60

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	49036.91	4	12259.23	4.38	0.0033
Treatment	49036.91	4	12259.23	4.38	0.0033
Error	187702.59	67	2801.53		
Total	236739.50	71			

Test : LSD Fisher Alfa: 0.05 DMS: 39.82040

Error: 2801.5312 gl: 67

Treatment	Medias	n			
5.00	195.80	16	A		
0.00	205.33	16	A	B	
20.00	243.63	9		B	C
10.00	245.75	16			C
15.00	265.69	15			C

Letras distintas indican diferencias significativas($p < 0.05$)

Chlorophyll 3:

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Chlorophyll	72	0.15	0.09	30.22

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	41694.24	4	10423.56	2.86	0.0300
Treatment	41694.24	4	10423.56	2.86	0.0300
Error	244349.04	67	3647.00		
Total	286043.28	71			

Test : LSD Fisher Alfa: 0.05 DMS: 45.43346

Error: 3647.0006 gl: 67

Treatment	Medias	n			
0.00	153.22	16	A		
5.00	191.00	15	A	B	
10.00	192.88	16	A	B	
15.00	207.53	16		B	
20.00	234.50	9		B	

Letras distintas indican diferencias significativas($p < 0.05$)

Photosynthesis 1:

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Photosynthesis	20	0.30	0.11	46.87

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	92.09	4	23.02	1.62	0.2217
Treatment	92.09	4	23.02	1.62	0.2217
Error	213.67	15	14.24		
Total	305.77	19			

Test : LSD Fisher Alfa: 0.05 DMS: 5.68838

Error: 14.2448 gl: 15

Treatment	Medias	n			
0.00	4.87	4	A		
5.00	7.47	4	A	B	
10.00	7.99	4	A	B	

15.00	8.35	4	A	B
20.00	11.58	4		B

Letras distintas indican diferencias significativas(p<=0.05)

Photosynthesis 2:

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Photosynthesis	19	0.28	0.07	31.04

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	54.86	4	13.71	1.35	0.3009
Treatment	54.86	4	13.71	1.35	0.3009
Error	142.33	14	10.17		
Total	197.19	18			

Test : LSD Fisher Alfa: 0.05 DMS: 4.97683

Error: 10.1667 gl: 14

Treatment	Medias	n		
0.00	6.69	4	A	
10.00	10.10	4	A	B
20.00	10.34	3	A	B
5.00	11.43	4	A	B
15.00	11.91	4		B

Letras distintas indican diferencias significativas(p<=0.05)

Appendix B**Statistical analyses for the field experiment**

QUADRATIC REGRESSION ANALISYS (240 DAP)

Modelo Green Forage Yield:=alfa*exp(-beta*exp(-gamma*Treatment))+delta

Variable	N	CMError	Iteracion
Green Forage Yield	12	16339510.61	3

Parametros	Estimación	E.E.	T	p
ALFA	54468.40	178922.31	0.30	0.7686
BETA	1.43	10.26	0.14	0.8925
GAMMA	0.00	0.01	0.55	0.5991
DELTA	55.59	176442.07	0.00	0.9998

QUADRATIC REGRESSION ANALISYS (270 DAP)

Modelo Green Forage Yield:=alfa*exp(-beta*exp(-gamma*Treatment))+delta

Variable	N	CMError	Iteracion
Green Forage Yield	11	41056230.75	3

Parametros	Estimación	E.E.	T	p
ALFA	55813.21	210292.63	0.27	0.7983
BETA	1.31	9.82	0.13	0.8974
GAMMA	0.00	0.01	0.45	0.6631
DELTA	9526.58	204146.91	0.05	0.9641

QUADRATIC REGRESSION ANALISYS (300 DAP)

Modelo Green Forage Yield:=alfa*exp(-beta*exp(-gamma*Treatment))+delta

Variable	N	CMError	Iteracion
Green Forage Yield	12	16734653.97	3

Parametros	Estimación	E.E.	T	p
ALFA	48903.99	71760.83	0.68	0.5148
BETA	1.61	5.51	0.29	0.7779
GAMMA	0.00	0.00	0.85	0.4181
DELTA	21000.71	68515.06	0.31	0.7670

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.97	0.96	8.61

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	3443772570.92	3	1147924190.31	89.11	<0.0001
Columnal	3443772570.92	3	1147924190.31	89.11	<0.0001
Error	103058708.00	8	12882338.50		
Total	3546831278.92	11			

Test : Duncan Alfa: 0.05

Error: 12882338.5000 gl: 8

Columnal	Medias	n	
1.00	12958.67	3	A
2.00	46420.67	3	B
3.00	51069.00	3	B C
4.00	56253.33	3	C

Letras distintas indican diferencias significativas(p<=0.05)

Dry Matter Content %

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.25	0.00	6.91

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	14.25	3	4.75	0.89	0.4864
Columnal	14.25	3	4.75	0.89	0.4864
Error	42.67	8	5.33		
Total	56.92	11			

Test : Duncan Alfa: 0.05

Error: 5.3333 gl: 8

Columnal	Medias	n	
2.00	32.00	3	A
3.00	33.00	3	A
1.00	33.67	3	A
4.00	35.00	3	A

Letras distintas indican diferencias significativas($p < 0.05$)

Dry Forage Yield (Kg/ha)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.97	0.96	9.22

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	401307292.33	3	133769097.44	81.05	<0.0001
Columnal	401307292.33	3	133769097.44	81.05	<0.0001
Error	13203591.33	8	1650448.92		
Total	414510883.67	11			

Test : Duncan Alfa: 0.05

Error: 1650448.9167 gl: 8

Columnal	Medias	n	
1.00	4371.33	3	A
2.00	14855.00	3	B
3.00	16858.33	3	B
4.00	19672.00	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Green Forage Yield (Kg/ha) (270 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.94	0.91	10.19

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	3255383142.92	3	1085127714.31	39.41	<0.0001
Columnal	3255383142.92	3	1085127714.31	39.41	<0.0001
Error	220261801.33	8	27532725.17		
Total	3475644944.25	11			

Test : Duncan Alfa: 0.05

Error: 27532725.1667 gl: 8

Columnal	Medias	n	
1.00	24172.33	3	A
2.00	54690.00	3	B
3.00	59406.00	3	B
4.00	67798.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Dry Matter Content

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.49	0.30	20.29

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	460.67	3	153.56	2.54	0.1300
Columnal	460.67	3	153.56	2.54	0.1300
Error	484.00	8	60.50		
Total	944.67	11			

Test : Duncan Alfa: 0.05

Error: 60.5000 gl: 8

Columnal	Medias	n		
1.00	31.33	3	A	
4.00	36.67	3	A	B
3.00	37.00	3	A	B
2.00	48.33	3		B

Letras distintas indican diferencias significativas($p < 0.05$)

Dry Forage Yield

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.89	0.84	16.15

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	659354566.00	3	219784855.33	20.90	0.0004
Columnal	659354566.00	3	219784855.33	20.90	0.0004
Error	84128722.67	8	10516090.33		
Total	743483288.67	11			

Test : Duncan Alfa: 0.05

Error: 10516090.3333 gl: 8

Columnal	Medias	n		
1.00	7495.33	3	A	
3.00	21975.00	3		B
4.00	24826.00	3		B
2.00	26021.00	3		B

Letras distintas indican diferencias significativas($p < 0.05$)

Green Forage Yield (300 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.96	0.94	6.97

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	2864692812.92	3	954897604.31	62.23	<0.0001
Columnal	2864692812.92	3	954897604.31	62.23	<0.0001
Error	122764106.00	8	15345513.25		
Total	2987456918.92	11			

Test : Duncan Alfa: 0.05

Error: 15345513.2500 gl: 8

Columnal	Medias	n		
1.00	30583.67	3	A	
2.00	57837.33	3		B
3.00	65789.67	3		C

4.00 70485.00 3 C
 Letras distintas indican diferencias significativas($p < 0.05$)

Dry Matter Content

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.45	0.24	5.63

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	36.92	3	12.31	2.17	0.1693
Columnal	36.92	3	12.31	2.17	0.1693
Error	45.33	8	5.67		
Total	82.25	11			

Test : Duncan Alfa: 0.05

Error: 5.6667 gl: 8

Columnal	Medias	n
3.00	40.00	3
1.00	41.33	3
4.00	43.00	3
2.00	44.67	3

Letras distintas indican diferencias significativas($p < 0.05$)

Dry Forage Yield

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.92	0.89	10.32

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	538587780.92	3	179529260.31	29.77	0.0001
Columnal	538587780.92	3	179529260.31	29.77	0.0001
Error	48236868.00	8	6029608.50		
Total	586824648.92	11			

Test : Duncan Alfa: 0.05

Error: 6029608.5000 gl: 8

Columnal	Medias	n
1.00	12599.67	3
2.00	25810.67	3
3.00	26316.00	3
4.00	30411.33	3

Letras distintas indican diferencias significativas($p < 0.05$)

(Fresh Weight)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Stem Weight	12	0.96	0.95	9.43

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1541284254.00	3	513761418.00	68.13	<0.0001
Tratamiento	1541284254.00	3	513761418.00	68.13	<0.0001
Error	60329894.67	8	7541236.83		
Total	1601614148.67	11			

Test : Duncan Alfa: 0.05

Error: 7541236.8333 gl: 8

Tratamiento	Medias	n
1.00	10042.67	3

2.00	32777.33	3	B
3.00	33872.33	3	B
4.00	39790.33	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Stem Weight	12	0.90	0.86	12.10

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1642036134.67	3	547345378.22	23.66	0.0002
Tratamiento	1642036134.67	3	547345378.22	23.66	0.0002
Error	185108662.00	8	23138582.75		
Total	1827144796.67	11			

Test : Duncan Alfa: 0.05

Error: 23138582.7500 gl: 8

Tratamiento	Medias	n	
1.00	20262.00	3	A
2.00	41842.67	3	B
3.00	45988.67	3	B
4.00	50897.33	3	B

Letras distintas indican diferencias significativas($p < 0.05$)**Análisis de la varianza**

Variable	N	R ²	R ² Aj	CV
Stem Weight	12	0.96	0.94	6.39

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1616766304.25	3	538922101.42	61.78	<0.0001
Tratamiento	1616766304.25	3	538922101.42	61.78	<0.0001
Error	69781940.00	8	8722742.50		
Total	1686548244.25	11			

Test : Duncan Alfa: 0.05

Error: 8722742.5000 gl: 8

Tratamiento	Medias	n	
1.00	26781.67	3	A
2.00	48322.67	3	B
3.00	53505.00	3	B
4.00	56397.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

(Fresh Weight)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Canopy Weight	12	0.89	0.86	20.46

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	83565037.58	3	27855012.53	22.69	0.0003
Tratamiento	83565037.58	3	27855012.53	22.69	0.0003
Error	9823178.67	8	1227897.33		
Total	93388216.25	11			

Test : Duncan Alfa: 0.05

Error: 1227897.3333 gl: 8

Tratamiento	Medias	n	
1.00	979.67	3	A
2.00	5973.33	3	B
4.00	6940.33	3	B
3.00	7769.67	3	B

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Canopy Weight	12	0.82	0.75	24.80

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	49981756.67	3	16660585.56	11.84	0.0026
Tratamiento	49981756.67	3	16660585.56	11.84	0.0026
Error	11256713.33	8	1407089.17		
Total	61238470.00	11			

Test : Duncan Alfa: 0.05

Error: 1407089.1667 gl: 8

Tratamiento	Medias	n			
1.00	1609.00	3	A		
2.00	4962.00	3		B	
3.00	5263.33	3		B	C
4.00	7297.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Canopy Weight	12	0.89	0.84	18.66

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	45024026.92	3	15008008.97	20.75	0.0004
Tratamiento	45024026.92	3	15008008.97	20.75	0.0004
Error	5785773.33	8	723221.67		
Total	50809800.25	11			

Test : Duncan Alfa: 0.05

Error: 723221.6667 gl: 8

Tratamiento	Medias	n			
1.00	1453.33	3	A		
2.00	4433.00	3		B	
3.00	5892.67	3		B	C
4.00	6448.00	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

(Fresh Weight)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Weight	12	0.90	0.86	17.83

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	114825116.25	3	38275038.75	23.63	0.0002
Tratamiento	114825116.25	3	38275038.75	23.63	0.0002
Error	12958208.67	8	1619776.08		
Total	127783324.92	11			

Test : Duncan Alfa: 0.05

Error: 1619776.0833 gl: 8

Tratamiento	Medias	n			
1.00	1935.67	3	A		
2.00	7670.00	3		B	
3.00	9427.00	3		B	
4.00	9523.00	3		B	

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Weight	12	0.96	0.94	10.24

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	92907420.25	3	30969140.08	60.51	<0.0001
Tratamiento	92907420.25	3	30969140.08	60.51	<0.0001
Error	4094574.00	8	511821.75		
Total	97001994.25	11			

Test : Duncan Alfa: 0.05

Error: 511821.7500 gl: 8

Tratamiento	Medias	n	
1.00	2301.67	3	A
2.00	7885.00	3	B
3.00	8154.67	3	B
4.00	9603.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Weight	12	0.91	0.87	14.39

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	46220216.25	3	15406738.75	25.83	0.0002
Tratamiento	46220216.25	3	15406738.75	25.83	0.0002
Error	4772076.67	8	596509.58		
Total	50992292.92	11			

Test : Duncan Alfa: 0.05

Error: 596509.5833 gl: 8

Tratamiento	Medias	n	
1.00	2348.67	3	A
2.00	5081.33	3	B
3.00	6392.33	3	B
4.00	7639.33	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

(Dry Weight)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Stem Weight	12	0.96	0.95	9.38

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	151592173.67	3	50530724.56	65.53	<0.0001
Tratamiento	151592173.67	3	50530724.56	65.53	<0.0001
Error	6168756.00	8	771094.50		
Total	157760929.67	11			

Test : Duncan Alfa: 0.05

Error: 771094.5000 gl: 8

Tratamiento	Medias	n	
1.00	3422.00	3	A

2.00	10211.33	3	B
3.00	11007.67	3	B
4.00	12799.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Stem Weight	12	0.85	0.79	18.46

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	354805268.25	3	118268422.75	14.98	0.0012
Tratamiento	354805268.25	3	118268422.75	14.98	0.0012
Error	63165908.67	8	7895738.58		
Total	417971176.92	11			

Test : Duncan Alfa: 0.05

Error: 7895738.5833 gl: 8

Tratamiento	Medias	n	
1.00	6012.33	3	A
3.00	16675.67	3	B
4.00	18311.33	3	B
2.00	19890.33	3	B

Letras distintas indican diferencias significativas($p < 0.05$)

(Dry Weight)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Stem Weight	12	0.90	0.86	10.46

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	246125651.33	3	82041883.78	24.26	0.0002
Tratamiento	246125651.33	3	82041883.78	24.26	0.0002
Error	27058877.33	8	3382359.67		
Total	273184528.67	11			

Test : Duncan Alfa: 0.05

Error: 3382359.6667 gl: 8

Tratamiento	Medias	n	
1.00	10004.33	3	A
3.00	19136.33	3	B
2.00	19166.00	3	B
4.00	22020.00	3	B

Letras distintas indican diferencias significativas($p < 0.05$)**Análisis de la varianza**

Variable	N	R ²	R ² Aj	CV
Canopy Weight	12	0.94	0.92	14.72

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	10368815.58	3	3456271.86	41.10	<0.0001
Tratamiento	10368815.58	3	3456271.86	41.10	<0.0001
Error	672683.33	8	84085.42		
Total	11041498.92	11			

Test : Duncan Alfa: 0.05

Error: 84085.4167 gl: 8

Tratamiento	Medias	n	
1.00	448.33	3	A
2.00	2015.00	3	B
3.00	2546.00	3	B
4.00	2868.33	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

(Dry Weight)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Canopy Weight	12	0.86	0.81	20.27

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	10230739.67	3	3410246.56	16.86	0.0008
Tratamiento	10230739.67	3	3410246.56	16.86	0.0008
Error	1617980.00	8	202247.50		
Total	11848719.67	11			

Test : Duncan Alfa: 0.05

Error: 202247.5000 gl: 8

Tratamiento	Medias	n	
1.00	665.67	3	A
3.00	2373.67	3	B
2.00	2915.00	3	B
4.00	2918.33	3	B

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Canopy Weight	12	0.94	0.91	12.37

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	13337404.92	3	4445801.64	38.43	<0.0001
Tratamiento	13337404.92	3	4445801.64	38.43	<0.0001
Error	925366.00	8	115670.75		
Total	14262770.92	11			

Test : Duncan Alfa: 0.05

Error: 115670.7500 gl: 8

Tratamiento	Medias	n	
1.00	986.67	3	A
2.00	2981.33	3	B
3.00	3285.67	3	B C
4.00	3748.00	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

(Dry Weight)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Weight	12	0.88	0.83	23.23

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	20624906.92	3	6874968.97	18.71	0.0006
Tratamiento	20624906.92	3	6874968.97	18.71	0.0006
Error	2939224.00	8	367403.00		
Total	23564130.92	11			

Test : Duncan Alfa: 0.05

Error: 367403.0000 gl: 8

Tratamiento	Medias	n	
1.00	500.67	3	A

2.00	2628.67	3		B
3.00	3304.33	3		B C
4.00	4004.00	3		C

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Weight	12	0.86	0.81	20.01

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	13946546.92	3	4648848.97	16.68	0.0008
Tratamiento	13946546.92	3	4648848.97	16.68	0.0008
Error	2230152.00	8	278769.00		
Total	16176698.92	11			

Test : Duncan Alfa: 0.05

Error: 278769.0000 gl: 8

Tratamiento	Medias	n	
1.00	817.33	3	A
3.00	2925.33	3	B
2.00	3215.67	3	B
4.00	3596.00	3	B

Letras distintas indican diferencias significativas($p < 0.05$)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Leaf Weight	12	0.89	0.85	13.97

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	15169808.25	3	5056602.75	21.74	0.0003
Tratamiento	15169808.25	3	5056602.75	21.74	0.0003
Error	1860704.67	8	232588.08		
Total	17030512.92	11			

Test : Duncan Alfa: 0.05

Error: 232588.0833 gl: 8

Tratamiento	Medias	n	
1.00	1609.00	3	A
2.00	3663.00	3	B
3.00	3894.00	3	B C
4.00	4643.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Photosynthesis (Leaf #2, 120 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.96	0.94	6.40

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	126.92	3	42.31	63.46	<0.0001
Columnal	126.92	3	42.31	63.46	<0.0001
Error	5.33	8	0.67		
Total	132.25	11			

Test : Duncan Alfa: 0.05

Error: 0.6667 gl: 8

Columnal	Medias	n	
1.00	8.67	3	A
2.00	11.00	3	B
3.00	14.00	3	C

4.00 17.33 3 D
 Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	10	0.97	0.95	7.08

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	151.73	3	50.58	58.74	0.0001
Columnal	151.73	3	50.58	58.74	0.0001
Error	5.17	6	0.86		
Total	156.90	9			

Test : Duncan Alfa: 0.05

Error: 0.8611 gl: 6

Columnal	Medias	n	
1.00	7.00	2	A
2.00	11.50	2	B
3.00	13.33	3	B
4.00	18.00	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (150 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.94	0.91	10.44

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	214.73	3	71.58	35.79	0.0001
Columnal	214.73	3	71.58	35.79	0.0001
Error	14.00	7	2.00		
Total	228.73	10			

Test : Duncan Alfa: 0.05

Error: 2.0000 gl: 7

Columnal	Medias	n	
1.00	5.00	2	A
2.00	12.67	3	B
3.00	16.33	3	C
4.00	17.33	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.92	0.89	12.35

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	229.58	3	76.53	31.67	0.0001
Columnal	229.58	3	76.53	31.67	0.0001
Error	19.33	8	2.42		
Total	248.92	11			

Test : Duncan Alfa: 0.05

Error: 2.4167 gl: 8

Columnal	Medias	n	
1.00	5.67	3	A
2.00	12.00	3	B
4.00	16.00	3	C

3.00 16.67 3 C
 Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (180 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.91	0.87	11.49

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	168.05	3	56.02	23.76	0.0005
Columnal	168.05	3	56.02	23.76	0.0005
Error	16.50	7	2.36		
Total	184.55	10			

Test : Duncan Alfa: 0.05

Error: 2.3571 gl: 7

Columnal	Medias	n			
1.00	5.50	2	A		
2.00	13.33	3		B	
3.00	15.33	3		B	C
4.00	16.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.95	0.93	5.62

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	46.05	3	15.35	42.98	0.0001
Columnal	46.05	3	15.35	42.98	0.0001
Error	2.50	7	0.36		
Total	48.55	10			

Test : Duncan Alfa: 0.05

Error: 0.3571 gl: 7

Columnal	Medias	n			
1.00	6.50	2	A		
2.00	10.67	3		B	
3.00	11.67	3		B	C
4.00	12.33	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (210 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.96	0.94	6.88

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	151.50	3	50.50	54.38	<0.0001
Columnal	151.50	3	50.50	54.38	<0.0001
Error	6.50	7	0.93		
Total	158.00	10			

Test : Duncan Alfa: 0.05

Error: 0.9286 gl: 7

Columnal	Medias	n			
1.00	6.50	2	A		
2.00	14.33	3		B	
3.00	15.33	3		B	
4.00	17.33	3			C

Letras distintas indican diferencias significativas($p < 0.05$)
Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.98	0.97	6.79

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	190.92	3	63.64	127.28	<0.0001
Columnal	190.92	3	63.64	127.28	<0.0001
Error	4.00	8	0.50		
Total	194.92	11			

Test : Duncan Alfa: 0.05

Error: 0.5000 gl: 8

Columnal	Medias	n			
1.00	3.67	3	A		
2.00	11.67	3		B	
3.00	12.33	3		B	
4.00	14.00	3			C

Letras distintas indican diferencias significativas($p < 0.05$)
Leaf #2 (240 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.92	0.88	10.04

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	154.17	3	51.39	26.00	0.0004
Columnal	154.17	3	51.39	26.00	0.0004
Error	13.83	7	1.98		
Total	168.00	10			

Test : Duncan Alfa: 0.05

Error: 1.9762 gl: 7

Columnal	Medias	n			
1.00	6.50	2	A		
2.00	14.00	3		B	
3.00	15.67	3		B	C
4.00	17.33	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.95	0.93	9.25

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	154.41	3	51.47	42.39	0.0001
Columnal	154.41	3	51.47	42.39	0.0001
Error	8.50	7	1.21		
Total	162.91	10			

Test : Duncan Alfa: 0.05

Error: 1.2143 gl: 7

Columnal	Medias	n			
1.00	4.50	2	A		
2.00	11.67	3		B	
3.00	13.67	3		B	C

4.00 15.33 3 C
 Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (270 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.95	0.93	6.32

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	104.30	3	34.77	45.63	0.0001
Columnal	104.30	3	34.77	45.63	0.0001
Error	5.33	7	0.76		
Total	109.64	10			

Test : Duncan Alfa: 0.05

Error: 0.7619 gl: 7

Columnal	Medias	n	
1.00	8.00	2	A
2.00	13.00	3	B
3.00	15.67	3	C
4.00	16.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.91	0.86	12.08

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	150.89	3	50.30	22.24	0.0006
Columnal	150.89	3	50.30	22.24	0.0006
Error	15.83	7	2.26		
Total	166.73	10			

Test : Duncan Alfa: 0.05

Error: 2.2619 gl: 7

Columnal	Medias	n	
1.00	5.50	2	A
2.00	12.33	3	B
3.00	13.00	3	B
4.00	16.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (300 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.97	0.96	5.88

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	158.05	3	52.68	81.95	<0.0001
Columnal	158.05	3	52.68	81.95	<0.0001
Error	4.50	7	0.64		
Total	162.55	10			

Test : Duncan Alfa: 0.05

Error: 0.6429 gl: 7

Columnal	Medias	n	
1.00	6.50	2	A
2.00	12.67	3	B
3.00	15.67	3	C

4.00 17.33 3 D
 Letras distintas indican diferencias significativas($p < 0.05$)
 Leaf#7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	10	0.88	0.83	13.28

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	132.27	3	44.09	15.26	0.0033
Columnal	132.27	3	44.09	15.26	0.0033
Error	17.33	6	2.89		
Total	149.60	9			

Test : Duncan Alfa: 0.05

Error: 2.8889 gl: 6

Columnal	Medias	n			
1.00	4.00	1	A		
2.00	10.67	3		B	
3.00	14.67	3			C
4.00	16.00	3			C

Letras distintas indican diferencias significativas($p < 0.05$)
 Relative Chlorophyll Content (120 DAP) Leaf#2

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.75	0.65	16.68

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	159553.00	3	53184.33	7.82	0.0092
Columnal	159553.00	3	53184.33	7.82	0.0092
Error	54430.00	8	6803.75		
Total	213983.00	11			

Test : Duncan Alfa: 0.05

Error: 6803.7500 gl: 8

Columnal	Medias	n			
1.00	337.33	3	A		
2.00	453.33	3	A	B	
3.00	534.00	3		B	C
4.00	653.33	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf#7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.85	0.79	12.31

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	159074.67	3	53024.89	15.07	0.0012
Columnal	159074.67	3	53024.89	15.07	0.0012
Error	28151.33	8	3518.92		
Total	187226.00	11			

Test : Duncan Alfa: 0.05

Error: 3518.9167 gl: 8

Columnal	Medias	n			
1.00	330.00	3	A		
2.00	440.00	3	A	B	
3.00	510.67	3		B	

4.00 647.33 3 C
 Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (150 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.74	0.64	14.08

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	173103.58	3	57701.19	7.55	0.0102
Columnal	173103.58	3	57701.19	7.55	0.0102
Error	61143.33	8	7642.92		
Total	234246.92	11			

Test : Duncan Alfa: 0.05

Error: 7642.9167 gl: 8

Columnal	Medias	n			
1.00	442.67	3	A		
2.00	594.00	3	A	B	
4.00	679.00	3		B	C
3.00	768.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.86	0.81	9.77

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	171291.58	3	57097.19	16.91	0.0008
Columnal	171291.58	3	57097.19	16.91	0.0008
Error	27011.33	8	3376.42		
Total	198302.92	11			

Test : Duncan Alfa: 0.05

Error: 3376.4167 gl: 8

Columnal	Medias	n			
1.00	409.33	3	A		
2.00	571.00	3		B	
4.00	691.33	3			C
3.00	708.00	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (180 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.91	0.88	9.49

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	279742.25	3	93247.42	28.50	0.0001
Columnal	279742.25	3	93247.42	28.50	0.0001
Error	26170.67	8	3271.33		
Total	305912.92	11			

Test : Duncan Alfa: 0.05

Error: 3271.3333 gl: 8

Columnal	Medias	n			
1.00	365.33	3	A		
2.00	574.67	3		B	
3.00	710.33	3			C

4.00 759.33 3 C
 Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.91	0.88	9.77

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	258784.67	3	86261.56	28.23	0.0001
Columnal	258784.67	3	86261.56	28.23	0.0001
Error	24447.33	8	3055.92		
Total	283232.00	11			

Test : Duncan Alfa: 0.05

Error: 3055.9167 gl: 8

Columnal	Medias	n	
1.00	344.00	3	A
2.00	525.33	3	B
3.00	677.00	3	C
4.00	717.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (210 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.94	0.92	9.19

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	362704.67	3	120901.56	40.50	<0.0001
Columnal	362704.67	3	120901.56	40.50	<0.0001
Error	23884.00	8	2985.50		
Total	386588.67	11			

Test : Duncan Alfa: 0.05

Error: 2985.5000 gl: 8

Columnal	Medias	n	
1.00	332.33	3	A
2.00	559.00	3	B
3.00	684.67	3	C
4.00	801.33	3	D

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.97	0.96	6.92

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	345565.33	3	115188.44	79.71	<0.0001
Columnal	345565.33	3	115188.44	79.71	<0.0001
Error	11561.33	8	1445.17		
Total	357126.67	11			

Test : Duncan Alfa: 0.05

Error: 1445.1667 gl: 8

Columnal	Medias	n	
1.00	296.33	3	A
2.00	511.00	3	B
3.00	637.00	3	C

4.00 754.33 3 D
 Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (240 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.93	0.90	8.60

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	315742.00	3	105247.33	35.41	0.0001
Columnal	315742.00	3	105247.33	35.41	0.0001
Error	23780.00	8	2972.50		
Total	339522.00	11			

Test : Duncan Alfa: 0.05

Error: 2972.5000 gl: 8

Columnal	Medias	n	
1.00	377.33	3	A
2.00	621.33	3	B
3.00	730.33	3	C
4.00	807.00	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.93	0.90	9.25

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	314642.92	3	104880.97	34.81	0.0001
Columnal	314642.92	3	104880.97	34.81	0.0001
Error	24105.33	8	3013.17		
Total	338748.25	11			

Test : Duncan Alfa: 0.05

Error: 3013.1667 gl: 8

Columnal	Medias	n	
1.00	336.67	3	A
2.00	589.33	3	B
3.00	673.00	3	C
4.00	774.00	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf #2 (270 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.92	0.89	9.43

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	316183.33	3	105394.44	30.73	0.0001
Columnal	316183.33	3	105394.44	30.73	0.0001
Error	27438.67	8	3429.83		
Total	343622.00	11			

Test : Duncan Alfa: 0.05

Error: 3429.8333 gl: 8

Columnal	Medias	n	
1.00	360.67	3	A
2.00	610.33	3	B
3.00	736.67	3	C

4.00 776.33 3 C
 Letras distintas indican diferencias significativas($p < 0.05$)
 Leaf#7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.91	0.88	10.19

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	268418.92	3	89472.97	27.56	0.0001
Columnal	268418.92	3	89472.97	27.56	0.0001
Error	25972.00	8	3246.50		
Total	294390.92	11			

Test : Duncan Alfa: 0.05

Error: 3246.5000 gl: 8

Columnal	Medias	n			
1.00	315.67	3	A		
2.00	563.33	3		B	
3.00	654.00	3		B	C
4.00	704.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf#2 (300 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.96	0.94	6.84

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	359879.00	3	119959.67	60.65	<0.0001
Columnal	359879.00	3	119959.67	60.65	<0.0001
Error	15822.00	8	1977.75		
Total	375701.00	11			

Test : Duncan Alfa: 0.05

Error: 1977.7500 gl: 8

Columnal	Medias	n			
1.00	362.67	3	A		
2.00	673.00	3		B	
3.00	756.67	3		B	C
4.00	809.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf#7

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.97	0.96	5.64

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	343288.25	3	114429.42	97.65	<0.0001
Columnal	343288.25	3	114429.42	97.65	<0.0001
Error	9374.67	8	1171.83		
Total	352662.92	11			

Test : Duncan Alfa: 0.05

Error: 1171.8333 gl: 8

Columnal	Medias	n			
1.00	327.67	3	A		
2.00	622.00	3		B	
3.00	720.00	3			C

4.00 760.00 3 C
 Letras distintas indican diferencias significativas($p < 0.05$)

0 N

Análisis de regresión no lineal

Modelo $Plant\ Height := \text{alfa} * \exp(-\text{beta} * \exp(-\text{gamma} * DAP))$

Variable	N	CMError	Iteracion
Plant Height	8	11.34	3

Parametros	Estimación	E.E.	T	p
ALFA	145.41	34.79	4.18	0.0087
BETA	2.34	0.20	11.91	0.0001
GAMMA	0.01	0.00	2.90	0.0337

448 N

Análisis de regresión no lineal

Modelo $Plant\ Height := \text{alfa} * \exp(-\text{beta} * \exp(-\text{gamma} * DAP)) + \text{delta}$

Variable	N	CMError	Iteracion
Plant Height	8	42.57	3

Parametros	Estimación	E.E.	T	p
ALFA	278.89	636.12	0.44	0.6837
BETA	2.00	6.38	0.31	0.7695
GAMMA	0.01	0.01	0.46	0.6695
DELTA	-21.46	404.67	-0.05	0.9602

896 N

Análisis de regresión no lineal

Modelo $Plant\ Height := \text{alfa} * \exp(-\text{beta} * \exp(-\text{gamma} * DAP)) + \text{delta}$

Variable	N	CMError	Iteracion
Plant Height	8	13.51	2

Parametros	Estimación	E.E.	T	p
ALFA	255.26	277.73	0.92	0.4101
BETA	1.94	3.58	0.54	0.6160
GAMMA	0.01	0.01	1.26	0.2769
DELTA	-25.98	228.56	-0.11	0.9150

1344 N

Análisis de regresión no lineal

Modelo $Plant\ Height := \text{alfa} * \exp(-\text{beta} * \exp(-\text{gamma} * Dap)) + \text{delta}$

Variable	N	CMError	Iteracion
Plant Height	8	17.00	3

Parametros	Estimación	E.E.	T	p
ALFA	450.67	1021.08	0.44	0.6818
BETA	1.10	3.54	0.31	0.7710
GAMMA	0.01	0.01	0.99	0.3761
DELTA	-176.12	949.24	-0.19	0.8618

Degree Days (Plant Height) 0 N**Análisis de regresión no lineal**

Modelo $Plant\ Height := \alpha * \exp(-\beta * \exp(-\gamma * DD)) + \delta$

Variable	N	CMError	Iteracion
Plant Height	8	14.87	2

Parametros	Estimación	E.E.	T	p
ALFA	133.11	231.99	0.57	0.5968
BETA	2.43	6.68	0.36	0.7347
GAMMA	0.00	0.00	0.57	0.5967
DELTA	3.22	143.39	0.02	0.9832

Degree Days (Plant Height) 448 N**Análisis de regresión no lineal**

Modelo $Plant\ Height := \alpha * \exp(-\beta * \exp(-\gamma * DD)) + \delta$

Variable	N	CMError	Iteracion
Plant Height	8	28.70	4

Parametros	Estimación	E.E.	T	p
ALFA	322.27	993.58	0.32	0.7619
BETA	1.29	5.81	0.22	0.8348
GAMMA	0.00	0.00	0.57	0.6022
DELTA	-96.49	876.85	-0.11	0.9177

Degree Days (Plant Height) 896 N**Análisis de regresión no lineal**

Modelo $Plant\ Height := \alpha * \exp(-\beta * \exp(-\gamma * DD)) + \delta$

Variable	N	CMError	Iteracion
Plant Height	8	16.48	2

Parametros	Estimación	E.E.	T	p
ALFA	221.75	199.43	1.11	0.3285
BETA	2.42	4.02	0.60	0.5790
GAMMA	0.00	0.00	1.32	0.2587
DELTA	3.02	153.80	0.02	0.9853

Degree Days (Plant Height) 1344 N**Análisis de regresión no lineal**

Modelo $Plant\ Height := \alpha * \exp(-\beta * \exp(-\gamma * DD)) + \delta$

Variable	N	CMError	Iteracion
Plant Height	8	28.46	3

Parametros	Estimación	E.E.	T	p
ALFA	210.82	91.93	2.29	0.0835
BETA	4.36	4.85	0.90	0.4193
GAMMA	0.00	0.00	2.25	0.0877
DELTA	29.76	68.02	0.44	0.6843

Number of tillers 0 N

Análisis de regresión no lineal

Modelo Number of Tillers:=alfa/(1+beta*exp(-gamma*DAP))

Variable	N	CMError	Iteracion
Number of Tillers	8	0.25	2

Parametros	Estimación	E.E.	T	p
ALFA	5.61	0.23	24.49	<0.0001
BETA	89024.24	357765.69	0.25	0.8134
GAMMA	0.09	0.03	2.76	0.0398

448 N

Análisis de regresión no lineal

Modelo Number of Tillers:=alfa/(1+beta*exp(-gamma*DAP))

Variable	N	CMError	Iteracion
Number of Tillers	7	0.19	2

Parametros	Estimación	E.E.	T	p
ALFA	9.57	0.29	33.53	<0.0001
BETA	174.31	124.94	1.40	0.2354
GAMMA	0.04	0.01	6.97	0.0022

896 N

Análisis de regresión no lineal

Modelo Number of Tillers:=alfa/(1+beta*exp(-gamma*DAP))

Variable	N	CMError	Iteracion
Number of Tillers	8	0.39	2

Parametros	Estimación	E.E.	T	p
ALFA	11.31	0.50	22.40	<0.0001
BETA	20.77	12.21	1.70	0.1497
GAMMA	0.03	0.01	4.99	0.0041

1344 N

Análisis de regresión no lineal

Modelo Number of Tillers:=alfa/(1+beta*exp(-gamma*DAP))

Variable	N	CMError	Iteracion
Number of Tillers	8	0.01	2

Parametros	Estimación	E.E.	T	p
ALFA	14.08	0.06	243.15	<0.0001
BETA	178.06	22.23	8.01	0.0005
GAMMA	0.04	0.00	41.16	<0.0001

Degree Days (number of tillers) 0 N**Análisis de regresión no lineal**

Modelo $\text{Number of Tillers} := \text{alfa} / (1 + \text{beta} * \exp(-\text{gamma} * \text{DD}))$

Variable	N	CMError	Iteracion
Number of Tillers	8	0.25	2

Parametros	Estimación	E.E.	T	p
ALFA	5.61	0.23	24.50	<0.0001
BETA	89019.96	359356.64	0.25	0.8142
GAMMA	0.01	0.00	2.75	0.0403

Degree Days (number of tillers) 448 N**Análisis de regresión no lineal**

Modelo $\text{Number of Tillers} := \text{alfa} / (1 + \text{beta} * \exp(-\text{gamma} * \text{DD}))$

Variable	N	CMError	Iteracion
Number of Tillers	8	0.19	2

Parametros	Estimación	E.E.	T	p
ALFA	9.41	0.24	40.01	<0.0001
BETA	199.30	146.68	1.36	0.2323
GAMMA	0.00	0.00	7.09	0.0009

Degree Days (number of tillers) 896 N**Análisis de regresión no lineal**

Modelo $\text{Number of Tillers} := \text{alfa} / (1 + \text{beta} * \exp(-\text{gamma} * \text{DD}))$

Variable	N	CMError	Iteracion
Number of Tillers	8	0.39	2

Parametros	Estimación	E.E.	T	p
ALFA	11.31	0.50	22.42	<0.0001
BETA	20.77	12.23	1.70	0.1503
GAMMA	0.00	0.00	4.98	0.0042

Degree Days (number of tillers) 1344 N**Análisis de regresión no lineal**

Modelo $\text{Number of Tillers} := \text{alfa} / (1 + \text{beta} * \exp(-\text{gamma} * \text{DD}))$

Variable	N	CMError	Iteracion
Number of Tillers	8	0.01	2

Parametros	Estimación	E.E.	T	p
ALFA	14.08	0.06	243.20	<0.0001
BETA	178.06	22.28	7.99	0.0005
GAMMA	0.00	0.00	41.06	<0.0001

Number of Leaves 0 N

Análisis de regresión no lineal

Modelo Number of Leaves:=alfa*exp(-beta*exp(-gamma*DAP))+delta

Variable	N	CMError	Iteracion
Number of Leaves	8	3.63	2

Parametros	Estimación	E.E.	T	p
ALFA	55.44	12.91	4.29	0.0127
BETA	14.22	14.29	1.00	0.3759
GAMMA	0.02	0.01	4.17	0.0141
DELTA	1.74	11.64	0.15	0.8885

Number of Leaves 448 N

Análisis de regresión no lineal

Modelo Number of Leaves:=alfa*exp(-beta*exp(-gamma*DAP))+delta

Variable	N	CMError	Iteracion
Number of Leaves	8	21.18	2

Parametros	Estimación	E.E.	T	p
ALFA	104.82	22.03	4.76	0.0089
BETA	32.54	41.03	0.79	0.4721
GAMMA	0.03	0.01	3.88	0.0178
DELTA	11.47	20.31	0.57	0.6022

Number of leaves 896 N

Análisis de regresión no lineal

Modelo Number of Leaves:=alfa*exp(-beta*exp(-gamma*DAP))+delta

Variable	N	CMError	Iteracion
Number of Leaves	8	34.12	16

Parametros	Estimación	E.E.	T	p
ALFA	148.35	91.92	1.61	0.1818
BETA	10.68	20.35	0.53	0.6273
GAMMA	0.02	0.01	2.64	0.0576
DELTA	-16.43	88.46	-0.19	0.8617

Number of Leaves 1344 N

Análisis de regresión no lineal

Modelo Number of Leaves:=alfa*exp(-beta*exp(-gamma*DAP))+delta

Variable	N	CMError	Iteracion
Number of Leaves	8	46.27	3

Parametros	Estimación	E.E.	T	p
ALFA	241.23	274.07	0.88	0.4285
BETA	4.61	11.04	0.42	0.6979
GAMMA	0.02	0.01	2.25	0.0874
DELTA	-73.97	267.40	-0.28	0.7958

Degree Days (number of leaves) 0 N

Análisis de regresión no lineal

Modelo $Number\ of\ Leaves := \alpha * \exp(-\beta * \exp(-\gamma * DD)) + \delta$

Variable	N	CMError	Iteracion
Number of Leaves	8	3.63	2

Parametros	Estimación	E.E.	T	p
ALFA	55.44	12.92	4.29	0.0127
BETA	14.22	14.32	0.99	0.3769
GAMMA	0.00	0.00	4.15	0.0142
DELTA	1.74	11.65	0.15	0.8886

Degree Days (number of leaves) 448 N

Análisis de regresión no lineal

Modelo $Number\ of\ Leaves := \alpha * \exp(-\beta * \exp(-\gamma * DD)) + \delta$

Variable	N	CMError	Iteracion
Number of Leaves	8	21.18	3

Parametros	Estimación	E.E.	T	p
ALFA	104.82	22.03	4.76	0.0089
BETA	32.54	41.13	0.79	0.4731
GAMMA	0.00	0.00	3.87	0.0180
DELTA	11.47	20.31	0.56	0.6023

Degree Days (number of leaves) 896 N

Análisis de regresión no lineal

Modelo $Number\ of\ Leaves := \alpha * \exp(-\beta * \exp(-\gamma * DD)) + \delta$

Variable	N	CMError	Iteracion
Number of Leaves	8	34.12	12

Parametros	Estimación	E.E.	T	p
ALFA	148.34	91.95	1.61	0.1820
BETA	10.69	20.39	0.52	0.6279
GAMMA	0.00	0.00	2.63	0.0580
DELTA	-16.41	88.49	-0.19	0.8619

Degree Days (number of leaves) 1344 N

Análisis de regresión no lineal

Modelo $Number\ of\ Leaves := \alpha * \exp(-\beta * \exp(-\gamma * DD)) + \delta$

Variable	N	CMError	Iteracion
Number of Leaves	8	48.09	2

Parametros	Estimación	E.E.	T	p
ALFA	184.87	110.55	1.67	0.1698
BETA	8.66	15.33	0.57	0.6022
GAMMA	0.00	0.00	2.65	0.0568
DELTA	-19.54	105.42	-0.19	0.8620

Leaf Area 0 N

Análisis de regresión no lineal

*Modelo Leaf Area:=alfa*exp(-beta*exp(-gamma*DAP))+delta*

Variable	N	CMError	Iteracion
Leaf Area	8	762828.40	3

Parametros	Estimación	E.E.	T	p
ALFA	11787.88	21031.31	0.56	0.6051
BETA	3.69	14.02	0.26	0.8056
GAMMA	0.01	0.02	0.52	0.6328
DELTA	-479.92	13099.37	-0.04	0.9725

Leaf Area 448 N

Análisis de regresión no lineal

*Modelo Leaf Area:=alfa*exp(-beta*exp(-gamma*DAP))+delta*

Variable	N	CMError	Iteracion
Leaf Area	8	29373696.22	2

Parametros	Estimación	E.E.	T	p
ALFA	126986.83	3670435.96	0.03	0.9741
BETA	0.88	30.53	0.03	0.9784
GAMMA	0.00	0.07	0.06	0.9540
DELTA	-59210.09	3207198.31	-0.02	0.9862

Leaf Area 896 N

Análisis de regresión no lineal

*Modelo Leaf Area:=alfa*exp(-beta*exp(-gamma*DAP))+delta*

Variable	N	CMError	Iteracion
Leaf Area	8	20918952.33	3

Parametros	Estimación	E.E.	T	p
ALFA	57183.38	129078.31	0.44	0.6807
BETA	3.50	17.84	0.20	0.8539
GAMMA	0.01	0.02	0.66	0.5462
DELTA	-9432.77	115685.28	-0.08	0.9389

Leaf Area 1344 N

Análisis de regresión no lineal

*Modelo Leaf Area:=alfa*exp(-beta*exp(-gamma*DAP))+delta*

Variable	N	CMError	Iteracion
Leaf Area	8	8302364.46	3

Parametros	Estimación	E.E.	T	p
ALFA	44473.99	12069.93	3.68	0.0211
BETA	19.13	28.57	0.67	0.5398
GAMMA	0.02	0.01	2.68	0.0550
DELTA	6803.37	10236.38	0.66	0.5426

Degree Days (Leaf Area) 0 N

Análisis de regresión no lineal

Modelo Leaf Area:=alfa*exp(-beta*exp(-gamma*DD))

Variable	N	CMError	Iteracion
Leaf Area	8	623802.51	2

Parametros	Estimación	E.E.	T	p
ALFA	10838.42	2959.86	3.66	0.0146
BETA	4.47	2.06	2.17	0.0826
GAMMA	0.00	0.00	2.09	0.0904

Degree Days (Leaf Area) 448 N

Análisis de regresión no lineal

Modelo Leaf Area:=alfa*exp(-beta*exp(-gamma*DD))

Variable	N	CMError	Iteracion
Leaf Area	8	25686098.62	15

Parametros	Estimación	E.E.	T	p
ALFA	49629.80	26255.91	1.89	0.1173
BETA	3.36	1.93	1.75	0.1412
GAMMA	0.00	0.00	1.15	0.3025

Degree Days (Leaf Area) 896 N

Análisis de regresión no lineal

Modelo Leaf Area:=alfa*exp(-beta*exp(-gamma*DD))+delta

Variable	N	CMError	Iteracion
Leaf Area	8	7622122.10	3

Parametros	Estimación	E.E.	T	p
ALFA	47958.89	17059.17	2.81	0.0483
BETA	12.15	18.66	0.65	0.5504
GAMMA	0.00	0.00	2.44	0.0714
DELTA	4375.39	14569.25	0.30	0.7789

Degree Days (Leaf Area) 1344 N

Análisis de regresión no lineal

Modelo Leaf Area:=alfa*exp(-beta*exp(-gamma*DD))+delta

Variable	N	CMError	Iteracion
Leaf Area	8	18625214.63	3

Parametros	Estimación	E.E.	T	p
ALFA	149618.48	2476670.63	0.06	0.9547
BETA	0.73	15.42	0.05	0.9647
GAMMA	0.00	0.00	0.27	0.8034
DELTA	-95030.31	2430467.24	-0.04	0.9707

Height (90 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.93	0.90	7.91

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	2282.25	3	760.75	35.66	0.0001
Columnal	2282.25	3	760.75	35.66	0.0001
Error	170.67	8	21.33		
Total	2452.92	11			

Test : Duncan Alfa: 0.05

Error: 21.3333 gl: 8

Columnal	Medias	n	
1.00	36.33	3	A
2.00	57.33	3	B
3.00	68.67	3	C
4.00	71.33	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

of Tillers

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.96	0.94	13.86

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	14.25	3	4.75	57.00	<0.0001
Columnal	14.25	3	4.75	57.00	<0.0001
Error	0.67	8	0.08		
Total	14.92	11			

Test : Duncan Alfa: 0.05

Error: 0.0833 gl: 8

Columnal	Medias	n	
1.00	0.33	3	A
2.00	2.00	3	B
3.00	3.00	3	C
4.00	3.00	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

of Leaves

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.84	0.78	17.78

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	716.25	3	238.75	13.77	0.0016
Columnal	716.25	3	238.75	13.77	0.0016
Error	138.67	8	17.33		
Total	854.92	11			

Test : Duncan Alfa: 0.05

Error: 17.3333 gl: 8

Columnal	Medias	n	
1.00	11.00	3	A
2.00	24.00	3	B
3.00	26.67	3	B
4.00	32.00	3	B

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf Area

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.99	0.99	5.60

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	93823472.06	3	31274490.69	277.23	<0.0001
Columnal	93823472.06	3	31274490.69	277.23	<0.0001
Error	789662.67	7	112808.95		
Total	94613134.73	10			

Test : Duncan Alfa: 0.05

Error: 112808.9524 gl: 7

Columnal	Medias	n	
1.00	1433.00	3	A
2.00	6565.00	3	B
3.00	7944.67	3	C
4.00	9078.00	2	D

Letras distintas indican diferencias significativas($p < 0.05$)

Height (120 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.87	0.82	11.78

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	4414.92	3	1471.64	17.62	0.0007
Columnal	4414.92	3	1471.64	17.62	0.0007
Error	668.00	8	83.50		
Total	5082.92	11			

Test : Duncan Alfa: 0.05

Error: 83.5000 gl: 8

Columnal	Medias	n	
1.00	46.33	3	A
2.00	78.33	3	B

3.00	89.00	3		B	C
4.00	96.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)
Tillers

Variable N	R ²	R ² Aj	CV	
Columna2	12	0.82	0.75	21.43

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	36.67	3	12.22	12.22	0.0023
Columnal	36.67	3	12.22	12.22	0.0023
Error	8.00	8	1.00		
Total	44.67	11			

Test : Duncan Alfa: 0.05

Error: 1.0000 gl: 8

Columnal	Medias	n			
1.00	2.00	3	A		
2.00	4.33	3		B	
3.00	5.67	3		B	C
4.00	6.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)
Leaves

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.78	0.70	24.48

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	5238.67	3	1746.22	9.40	0.0053
Columnal	5238.67	3	1746.22	9.40	0.0053
Error	1486.00	8	185.75		
Total	6724.67	11			

Test : Duncan Alfa: 0.05

Error: 185.7500 gl: 8

Columnal	Medias	n			
1.00	22.00	3	A		
2.00	57.33	3		B	
3.00	64.67	3		B	
4.00	78.67	3		B	

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf Area

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.95	0.93	13.96

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	544436404.33	3	181478801.44	46.39	<0.0001
Columnal	544436404.33	3	181478801.44	46.39	<0.0001
Error	31298291.33	8	3912286.42		
Total	575734695.67	11			

Test : Duncan Alfa: 0.05

Error: 3912286.4167 gl: 8

Columnal	Medias	n			
1.00	2722.33	3	A		
2.00	16135.00	3		B	
3.00	17943.33	3		B	
4.00	19856.00	3		B	

Letras distintas indican diferencias significativas($p < 0.05$)

Height (150 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.86	0.81	13.11

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	9037.67	3	3012.56	16.36	0.0009
Columnal	9037.67	3	3012.56	16.36	0.0009
Error	1473.33	8	184.17		
Total	10511.00	11			

Test : Duncan Alfa: 0.05

Error: 184.1667 gl: 8

Columnal	Medias	n	
1.00	58.67	3	A
2.00	106.33	3	B
3.00	117.00	3	B
4.00	132.00	3	B

Letras distintas indican diferencias significativas($p < 0.05$)

Tillers

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.82	0.74	17.86

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	60.85	3	20.28	10.65	0.0053
Columnal	60.85	3	20.28	10.65	0.0053
Error	13.33	7	1.90		
Total	74.18	10			

Test : Duncan Alfa: 0.05

Error: 1.9048 gl: 7

Columnal	Medias	n	
1.00	4.67	3	A
2.00	7.33	3	A B
3.00	8.00	2	B
4.00	11.00	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaves

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.95	0.93	8.93

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	7713.67	3	2571.22	50.17	<0.0001
Columnal	7713.67	3	2571.22	50.17	<0.0001
Error	410.00	8	51.25		
Total	8123.67	11			

Test : Duncan Alfa: 0.05

Error: 51.2500 gl: 8

Columnal	Medias	n	
1.00	39.00	3	A
2.00	82.67	3	B
3.00	91.67	3	B

4.00 107.33 3 C
 Letras distintas indican diferencias significativas($p < 0.05$)

Leaf Area

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.90	0.86	19.33

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1138995983.33	3	379665327.78	23.45	0.0003
Columnal	1138995983.33	3	379665327.78	23.45	0.0003
Error	129530960.67	8	16191370.08		
Total	1268526944.00	11			

Test : Duncan Alfa: 0.05

Error: 16191370.0833 gl: 8

Columnal	Medias	n			
1.00	4736.33	3	A		
2.00	21972.67	3		B	
3.00	26188.33	3		B	C
4.00	30350.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)
 Height (180 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.84	0.79	13.34

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	10590.92	3	3530.31	14.43	0.0014
Columnal	10590.92	3	3530.31	14.43	0.0014
Error	1957.33	8	244.67		
Total	12548.25	11			

Test : Duncan Alfa: 0.05

Error: 244.6667 gl: 8

Columnal	Medias	n			
1.00	69.33	3	A		
2.00	120.00	3		B	
3.00	129.67	3		B	
4.00	150.00	3		B	

Letras distintas indican diferencias significativas($p < 0.05$)
 # Tillers

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	10	0.91	0.86	11.63

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	71.23	3	23.74	19.88	0.0016
Columnal	71.23	3	23.74	19.88	0.0016
Error	7.17	6	1.19		
Total	78.40	9			

Test : Duncan Alfa: 0.05

Error: 1.1944 gl: 6

Columnal	Medias	n			
1.00	5.50	2	A		
2.00	8.67	3		B	
3.00	9.00	2		B	
4.00	13.00	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

#Leaves

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.96	0.95	7.37

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	12080.30	3	4026.77	62.18	<0.0001
Columnal	12080.30	3	4026.77	62.18	<0.0001
Error	453.33	7	64.76		
Total	12533.64	10			

Test : Duncan Alfa: 0.05

Error: 64.7619 gl: 7

Columnal	Medias	n	
1.00	45.00	2	A
2.00	108.00	3	B
3.00	118.67	3	B
4.00	143.67	3	C

Letras distintas indican diferencias significativas(p<=0.05)

Leaf Area

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.77	0.68	32.60

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	2057619974.67	3	685873324.89	8.90	0.0063
Columnal	2057619974.67	3	685873324.89	8.90	0.0063
Error	616673458.00	8	77084182.25		
Total	2674293432.67	11			

Test : Duncan Alfa: 0.05

Error: 77084182.2500 gl: 8

Columnal	Medias	n	
1.00	5827.67	3	A
2.00	27450.33	3	B
3.00	33467.00	3	B
4.00	40985.67	3	B

Letras distintas indican diferencias significativas(p<=0.05)

Height (210 DAP)

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.89	0.84	11.34

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	13539.33	3	4513.11	20.77	0.0004
Columnal	13539.33	3	4513.11	20.77	0.0004
Error	1738.67	8	217.33		
Total	15278.00	11			

Test : Duncan Alfa: 0.05

Error: 217.3333 gl: 8

Columnal	Medias	n	
1.00	75.67	3	A
2.00	133.33	3	B
3.00	144.33	3	B
4.00	166.67	3	C

Letras distintas indican diferencias significativas(p<=0.05)

Tillers

Variable	N	R ²	R ² Aj	CV
Columna2	10	0.87	0.80	16.75

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	102.27	3	34.09	12.92	0.0050
Columnal	102.27	3	34.09	12.92	0.0050
Error	15.83	6	2.64		
Total	118.10	9			

Test : Duncan Alfa: 0.05

Error: 2.6389 gl: 6

Columnal	Medias	n	
1.00	4.50	2	A
2.00	9.00	2	B
3.00	9.67	3	B
4.00	13.67	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaves

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.96	0.95	8.13

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	14326.00	3	4775.33	64.68	<0.0001
Columnal	14326.00	3	4775.33	64.68	<0.0001
Error	590.67	8	73.83		
Total	14916.67	11			

Test : Duncan Alfa: 0.05

Error: 73.8333 gl: 8

Columnal	Medias	n	
1.00	50.00	3	A
2.00	109.00	3	B
3.00	119.67	3	B
4.00	144.00	3	C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf Area

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.78	0.69	33.89

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	2025354315.39	3	675118105.13	8.49	0.0099
Columnal	2025354315.39	3	675118105.13	8.49	0.0099
Error	556518663.33	7	79502666.19		
Total	2581872978.73	10			

Test : Duncan Alfa: 0.05

Error: 79502666.1905 gl: 7

Columnal	Medias	n	
1.00	6020.00	3	A
2.00	27481.33	3	B
3.00	33642.67	3	B
4.00	43986.00	2	B

Letras distintas indican diferencias significativas($p < 0.05$)

Height (240 DAP)

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.85	0.80	14.06

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	18188.92	3	6062.97	15.31	0.0011
Columnal	18188.92	3	6062.97	15.31	0.0011
Error	3168.00	8	396.00		
Total	21356.92	11			

Test : Duncan Alfa: 0.05

Error: 396.0000 gl: 8

Columnal	Medias	n			
1.00	79.67	3	A		
2.00	142.00	3		B	
3.00	159.33	3		B	C
4.00	185.33	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Tillers

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.83	0.76	16.77

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	93.58	3	31.19	11.29	0.0045
Columnal	93.58	3	31.19	11.29	0.0045
Error	19.33	7	2.76		
Total	112.91	10			

Test : Duncan Alfa: 0.05

Error: 2.7619 gl: 7

Columnal	Medias	n			
1.00	5.00	2	A		
2.00	9.00	3		B	
3.00	10.33	3		B	C
4.00	13.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaves

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.96	0.95	8.11

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	15857.67	3	5285.89	66.70	<0.0001
Columnal	15857.67	3	5285.89	66.70	<0.0001
Error	634.00	8	79.25		
Total	16491.67	11			

Test : Duncan Alfa: 0.05

Error: 79.2500 gl: 8

Columnal	Medias	n			
1.00	53.00	3	A		
2.00	111.33	3		B	
3.00	121.33	3		B	
4.00	153.67	3			C

Letras distintas indican diferencias significativas($p \leq 0.05$)

Leaf Area

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.79	0.70	33.33

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	2181166098.85	3	727055366.28	8.83	0.0089
Columnal	2181166098.85	3	727055366.28	8.83	0.0089
Error	576615039.33	7	82373577.05		
Total	2757781138.18	10			

Test : Duncan Alfa: 0.05

Error: 82373577.0476 gl: 7

Columnal	Medias	n	
1.00	6085.33	3	A
2.00	28584.00	3	B
3.00	34959.33	3	B
4.00	45329.00	2	B

Letras distintas indican diferencias significativas($p \leq 0.05$)

Height (270 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.85	0.80	13.31

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	19577.67	3	6525.89	15.50	0.0011
Columnal	19577.67	3	6525.89	15.50	0.0011
Error	3368.00	8	421.00		
Total	22945.67	11			

Test : Duncan Alfa: 0.05

Error: 421.0000 gl: 8

Columnal	Medias	n	
1.00	89.33	3	A
2.00	156.67	3	B
3.00	171.67	3	B
4.00	199.00	3	C

Letras distintas indican diferencias significativas($p \leq 0.05$)

Tillers

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.74	0.62	19.41

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	76.30	3	25.43	6.51	0.0195
Columnal	76.30	3	25.43	6.51	0.0195
Error	27.33	7	3.90		
Total	103.64	10			

Test : Duncan Alfa: 0.05

Error: 3.9048 gl: 7

Columnal	Medias	n			
1.00	6.00	2	A		
2.00	9.00	3	A	B	
3.00	10.67	3		B	C
4.00	13.67	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaves

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.97	0.95	7.59

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	16376.92	3	5458.97	74.61	<0.0001
Columnal	16376.92	3	5458.97	74.61	<0.0001
Error	585.33	8	73.17		
Total	16962.25	11			

Test : Duncan Alfa: 0.05

Error: 73.1667 gl: 8

Columnal	Medias	n			
1.00	55.33	3	A		
2.00	111.67	3		B	
3.00	127.00	3		B	
4.00	157.00	3			C

Letras distintas indican diferencias significativas($p < 0.05$)

Leaf Area

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.81	0.74	27.34

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	2497329234.00	3	832443078.00	11.62	0.0028
Columnal	2497329234.00	3	832443078.00	11.62	0.0028
Error	573193508.67	8	71649188.58		
Total	3070522742.67	11			

Test : Duncan Alfa: 0.05

Error: 71649188.5833 gl: 8

Columnal	Medias	n			
1.00	8859.67	3	A		
2.00	28894.67	3		B	

3.00	38151.33	3	B	C
4.00	47931.67	3		C

Letras distintas indican diferencias significativas ($p < 0.05$) Height (300 DAP)

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.87	0.82	11.78

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	20833.58	3	6944.53	17.30	0.0007
Columnal	20833.58	3	6944.53	17.30	0.0007
Error	3211.33	8	401.42		
Total	24044.92	11			

Test : Duncan Alfa: 0.05

Error: 401.4167 gl: 8

Columnal	Medias	n		
1.00	103.00	3	A	
2.00	174.67	3		B
3.00	186.00	3		B
4.00	216.67	3		C

Letras distintas indican diferencias significativas ($p < 0.05$)

Tillers

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	11	0.70	0.57	19.76

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	73.64	3	24.55	5.37	0.0311
Columnal	73.64	3	24.55	5.37	0.0311
Error	32.00	7	4.57		
Total	105.64	10			

Test : Duncan Alfa: 0.05

Error: 4.5714 gl: 7

Columnal	Medias	n		
1.00	6.00	2	A	
2.00	10.33	3	A	B
3.00	11.67	3		B
4.00	13.67	3		B

Letras distintas indican diferencias significativas ($p < 0.05$)

Leaves

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.94	0.91	10.81

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	19713.58	3	6571.19	38.39	<0.0001
Columnal	19713.58	3	6571.19	38.39	<0.0001
Error	1369.33	8	171.17		
Total	21082.92	11			

Test : Duncan Alfa: 0.05

Error: 171.1667 gl: 8

Columnal	Medias	n		
1.00	57.67	3	A	
2.00	120.67	3		B
3.00	137.00	3		B
4.00	169.00	3		C

Letras distintas indican diferencias significativas ($p < 0.05$)

Leaf Area

Análisis de la varianza

Variable	N	R ²	R ² Aj	CV
Columna2	12	0.79	0.72	28.50

Cuadro de Análisis de la Varianza (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	3877211774.92	3	1292403924.97	10.26	0.0041
Columnal	3877211774.92	3	1292403924.97	10.26	0.0041
Error	1008054350.00	8	126006793.75		
Total	4885266124.92	11			

Test : Duncan Alfa: 0.05

Error: 126006793.7500 gl: 8

Columnal	Medias	n	
1.00	8873.33	3	A
2.00	44395.00	3	B
3.00	49741.33	3	B
4.00	54520.67	3	B

Letras distintas indican diferencias significativas($p \leq 0.05$)