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CLASSIC GROWTH ANALYSIS IN THREE POTATO (*Solanum tuberosum* L.) VARIETIES

Análisis clásico del crecimiento en tres variedades de papa (*Solanum tuberosum* L.)

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ABSTRACT. Dry biomass and leaf area growth data were collected every decennial from three potato varieties developed under field conditions at the experimental areas of the National Institute of Agricultural Sciences, with the aim of evaluating the behaviour of different growth indexes: Leaf Area Index (LAI), Net Assimilation Rate (NAR), Relative Growth Rate (RGR) and Crop Growth Rate (CGR), as well as Source Power (SP) and Demand Power (DP). Thus, seed tubers imported from Call White, Santana and Spunta varieties were planted in three plots following a sample design during 2010 and 2011. Cultural farming was performed according to the Technical Instructions for potato crop. Samplings to gather primary data started 30 days after planting until harvesting. Every time, 10 plants were randomly sampled per each variety, in order to know by oven drying the amount of dry biomass produced in different organs and to estimate leaf area from linear measurements of leaves as well as using previously obtained regression equations. Mean, maximum and minimum temperatures were recorded along crop cycle. Differences on the indexes evaluated were detected between varieties. Likewise, the influence of temperatures on growth is discussed in general, due to its importance in dry mass production.

Key words: biomass, physiology, leaf area, temperature, growth rate

RESUMEN. Con el objetivo de evaluar el comportamiento de diferentes índices del crecimiento: Índice de Área Foliar (IAF), Tasa de Asimilación Neta (TAN), Tasa Relativa del Crecimiento (TRC), y Tasa de Crecimiento del Cultivo (TCC); así como también la Potencia o Fuerza de la Fuente (FF) y de la Demanda (FD), se colectaron datos con una frecuencia decenal del crecimiento en biomasa seca y superficie foliar, de tres variedades de papa que se desarrollaron en condiciones de campo en áreas experimentales del Instituto Nacional de Ciencias Agrícolas. Las plantaciones se realizaron con tubérculos de semillas importados de las variedades Call White, Spunta y Santana, plantadas en tres parcelas siguiendo un Diseño Muestral, durante los años 2010 y 2011. Las atenciones culturales se realizaron según lo recomendado en el Instructivo Técnico para el cultivo. Los muestreos para la colecta de la información primaria, comenzaron a partir de los 30 días después de la plantación y hasta la cosecha. En cada momento se muestrearon 10 plantas al azar por cada variedad, para conocer mediante secado en estufa la cantidad de biomasa seca producida en los diferentes órganos y la estimación de la superficie foliar a partir de las medidas lineales de las hojas y el empleo de ecuaciones de regresión previamente obtenidas. Durante el ciclo del cultivo se registraron las temperaturas medias, máximas y mínimas ocurridas en ese periodo. Se detectaron diferencias entre variedades en relación a los índices evaluados. Asimismo, se discute la influencia de las temperaturas en el crecimiento en general, por su importancia en la producción de masa seca.

Palabras clave: biomasa, fisiología, superficie foliar, temperatura, velocidad de crecimiento

INTRODUCTION

The growth of higher plants has been defined as the irreversible size increase of an organism, simply resulting from the interaction of multiple physiological and biochemical processes, such as: water and nutrient absorption, carbon assimilation and synthesized

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material distribution to different plant organs, which are eventually determined by the balance of plant growth regulators and gene provision characterizing any organism (1).

On the other hand, it is also defined as plant size increased in time, generally associated with a rise in dry mass, although it is not so necessary. Plant growth constitutes a true reflection of a number of structural changes in specific size, weight and form, which take place according to cell division and differentiation patterns that cannot be considered outside the environmental context (2).

Growth analysis is a quantitative approach to understand plant or plant population growth under natural or controlled environmental conditions (3); at the same time, it permits to get important information referred to continue the work from simulating growth and thereby yield. It has been widely used to study the factors influencing plant development and yield, by means of monitoring dry matter accumulation over time.

Mathematical growth analysis uses direct measures, such as Dry Weight (DW), Total Leaf Area (LA) and Time (T) whereas derived measures: Relative Growth Rate (RGR), Net Assimilation Rate (NAR), Crop Growth Rate (CGR) and Leaf Area Index (LAI), among others, are calculated from the relationship established between direct measures (4).

Considering that Call White, Spunta and Santana varieties occupied an important production area when the research was conducted; the proposed objective of this work was to assess their physiological behavior under field conditions by different growth rates using the classical approach, which will enable to perform future growth simulation works in this crop.

MATERIALS AND METHODS

The research work was carried out at the experimental areas of the National Institute of Agricultural Sciences (INCA), following a sample design to plant three blocks of 0,03 ha per each variety in a Compacted Eutric Red Ferralitic soil during the first half of January 2010 and 2011 (5), in every case using larger seed tubers than 45 mm, imported from Call White (Canadian), Spunta and Santana (Dutch) varieties within a planting frame of 0,30 x 0,90 m (one plot of 252 m^2 per variety). At that time, these varieties occupied a significant volume in different plantations of the country.

Cultural practices followed the Technical Instruction for this crop (6), in this case including sprinkler irrigation through a central pivot machine. While the experiments remained in the field, maximum, minimum and mean temperatures were recorded at the Meteorological Station next to the experimental area and data from three variables were processed every decennial.

By destructive samplings of 10 plants per each variety, randomly taken from the experimental plot, and after separating different plant organs (roots, stems and leaves) and placing them in an oven at 80 ^oC until constant mass, then dry mass was obtained. In the case of tubers, dry mass percentage was determined every sampling time, which represents the amount of dry mass present in 100 g fresh mass, so that from their total fresh mass, the accumulated dry mass was calculated by a simple rule of three. Leaf area was recorded from linear measures of leaves and regression equations previously obtained (7).

Having the information of leaf area and dry mass variables, the following growth indexes were calculated: Leaf Area Index (LAI), Net Assimilation Rate (NAR), Relative Growth Rate (RGR) and Crop Growth Rate (CGR). In addition, Source Power (SP) and Demand Power (DP) of each variety were determined throughout the cycle by using the classical growth analysis approach (8). Data were statistically processed to calculate mean confidence interval in each sampling time at a level of α= 0,05.

RESULTS AND DISCUSSION

Figure 1 shows the behavior of maximum, minimum and mean temperatures during three experimental years. The ranges of values achieved every year were similar; in 2010, maximum temperatures showed the lowest values and stayed longer in that condition, whereas minimum temperatures were higher in 2011.

It has been pointed out that both the photoperiod and temperatures are the most important climatic elements influencing potato growth and development (9).

On the other hand, it is stated that quick temperature variations, as it occurred in 2011, affect general crop behavior (10), which results in lower yields and dry mass production. Similarly, it has been suggested that overall crop production will largely result from multiple relationships established between climatic elements and potato plants (11).

Figure 2 presents Leaf Area Index (LAI). On average, higher values were recorded in Call White and Spunta varieties during 2010 than in 2011; however, Santana variety showed similar values in both years. Maximum LAI values were displaced, since Call White and Santana varieties attained them 60 Days after Planting (DAP) in 2010, unlike what happened in 2011, that the maximum LAI was reached 50 DAP. Spunta variety achieved the maximum value 50 DAP in both years, showing a slower growth.

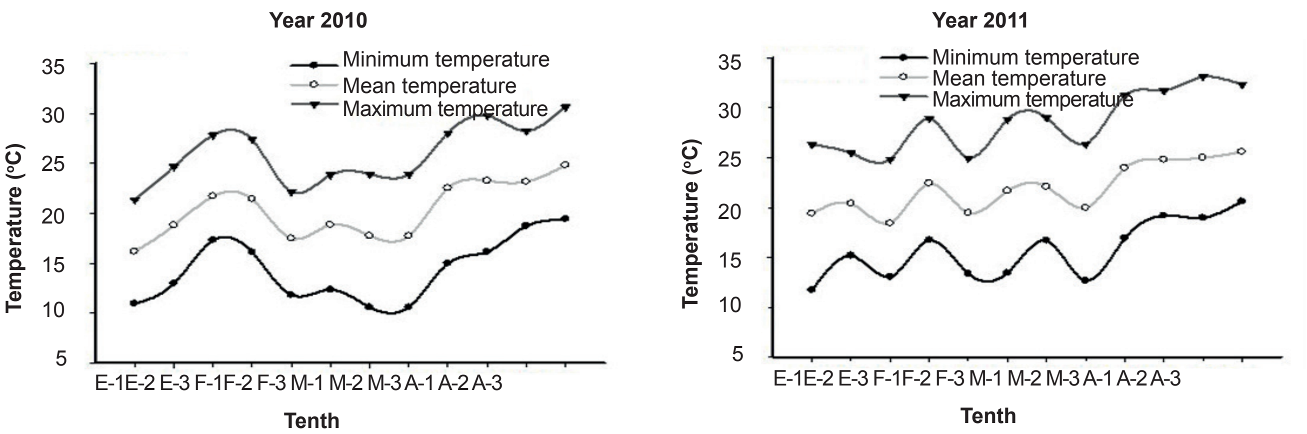

Figure 1. Behavior of maximum, minimum and mean temperatures during plantation in 2010 and 2011

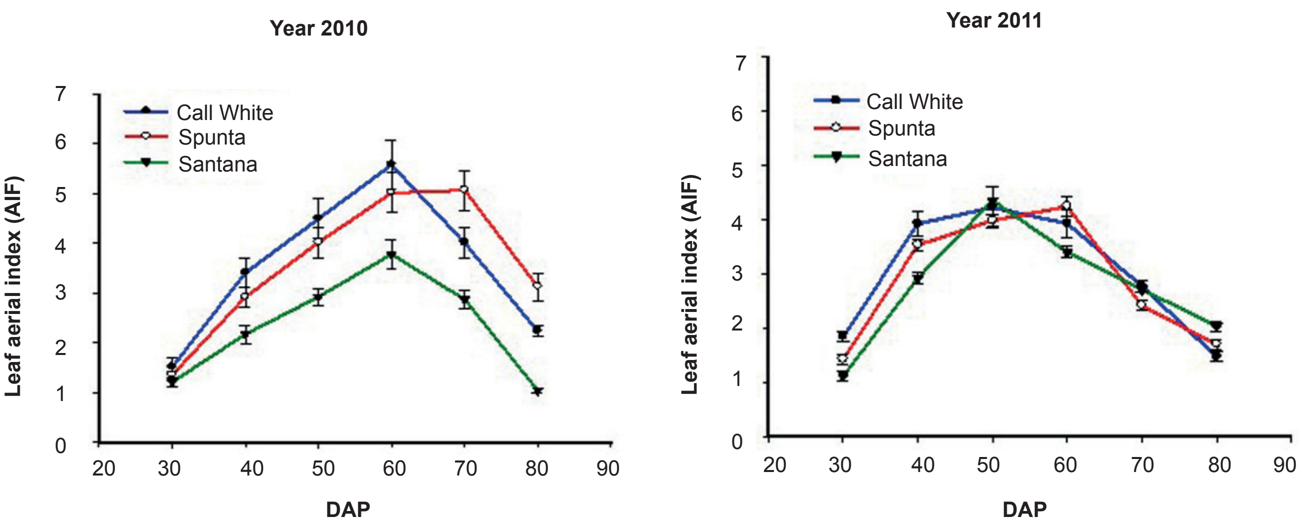

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Figure 2. Behavior of Leaf Aerial Index (LAI) in three potato varieties planted in 2010 and 2011

Maximum values coincided in time with maximum foliage, that is, when the soil was completely covered.

A high LAI is in correspondence with leaf surface size; thus, Call White variety presented a greater value of this variable than the other materials evaluated (7).

LAI represents the relationship between plant photosynthesizing area and its projection in the soil, varying with leaf shape and both vertical and horizontal foliage distribution; besides, this indicator is widely used to show aerial part architecture (4).

Foliage structure plays a key role in the exchanging process of matter and energy between the plant and the atmosphere, so that describing its status and condition constitutes a priority and main objective in plant growth studies (12, 13). A maximum LAI may be related to the greatest assimilate distribution from the leaves to the tubers; meanwhile a lower LAI could ensure a higher exposure of the remaining leaves to photosynthetically active radiation (PAR), securing a greater photosynthetic efficiency.

Figure 3 presents Net Assimilation Rate (NAR). The values of this indicator were in correspondence with those discussed above for LAI. The highest NAR values corresponded to the lowest LAI values, as it was observed in 2011 plantation. In this sense, Santana variety that reached the lowest LAI values presented the highest NAR values in both plantations.

Maximum NAR was reached at 50 days in both plantations; since that moment, assimilate distribution from the aerial part to the tubers is an important element, because its values generally decrease, with small variations that could be due to the environment, which could be demonstrated by temperature behavior in 2010, which decreased and remained in that condition for a longer time (Figure 1), meanwhile in 2011, they were more fluctuating, with periodic descents and ascents. The behavior of Spunta variety showed late maturing, like Santana variety, Call White being much earlier. Although this situation was not accurately detected under the experimental conditions of this work, since the three varieties had a similar cycle, it could be stated when analyzing growth through different indexes (9) involving both variables for its calculation.

On the other hand, NAR is the efficiency index of plant production, calculated according to total leaf area and constitutes a measure of net photosynthetic activity. It indicates plant ability to increase weight in terms of assimilatory area and internal control processes related to assimilate process and demand (8).

The behavior of NAR in evaluated potato cultivars is different from that observed in other plant species, as reserve accumulation occurs in tubers and not in the aerial part of the plant; that is why this rate can increase towards the end of crop cycle, due to a high demand activity (tubers).

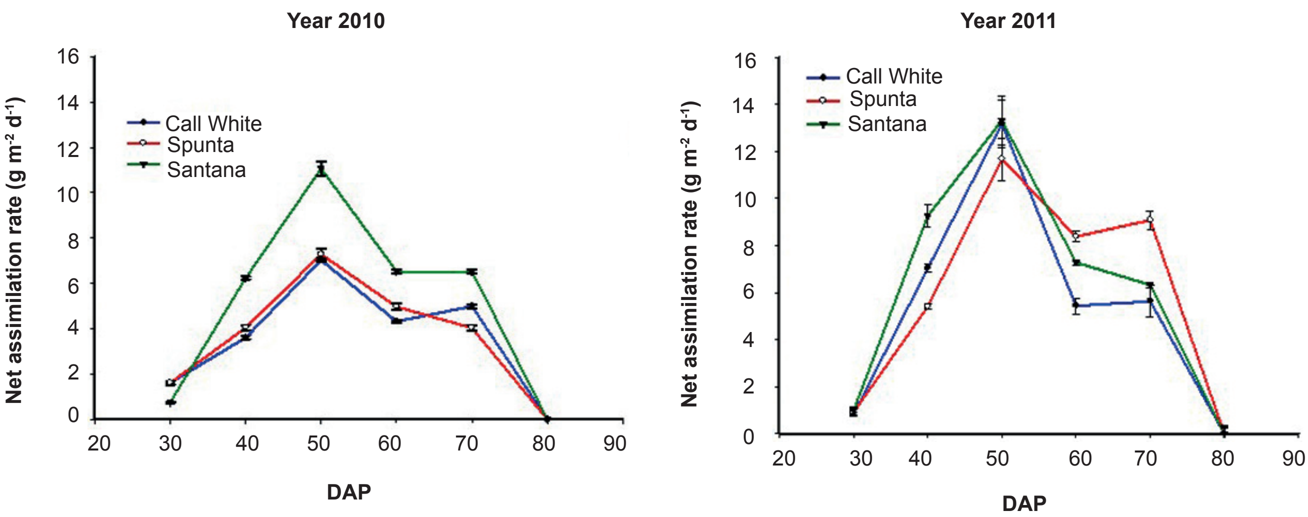

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Figure 3. Behavior of Net Assimilation Rate (NAR) in three potato varieties planted in 2010 and 2011

Figure 4 shows the behavior of Relative Growth Rate (RGR), which represents plant ability to produce new material per unit of time; it is affected by differences recorded in net assimilation rate, respiratory rate, leaf blade thickness and product distribution. Santana variety showed a similar growth pattern for this indicator in both years evaluated, with slight increases at the beginning (30-40 DAP) and decreases up to the final evaluation.

Call White and Spunta varieties had similar values in 2010 plantation, with a decrease since the first evaluation but slight increases towards 50 DAP. Call White variety was notable at the end of the cycle, due to a slight increase compared to the others, which indicates certain increase in dry mass production and could prove its translocation to tubers was not so efficient.

Call White and Santana varieties in the second plantation (2011, Figure 4) had a higher dry mass accumulation per unit of time than at the beginning, compared to Spunta variety at the early stages of crop cycle.

The behavior of RGR showed a similar pattern to what happened in the second plantation, that is, increases at the beginning of crop cycle with decreases in values from a certain moment when site demand activity (tubers) is intensified by the need of assimilates.

Potato crop in tropical climate is characterized by facing supra-optimal temperature behavior (14, 15), although these areas are also characterized by higher values of solar energy throughout the year. High values of solar energy enhance the tendency of tuber formation with high temperature. Short cycle potatoes, as Call White variety, require high light intensity, short photoperiod, high temperatures and restricted humidity to achieve the best results. However, it is interesting and necessary to keep on working with potato crop and its adaptation to climatic changes (16), as well as on the effects upon growth and development process of different cultivars.

Figure 5 shows Crop Growth Rate (CGR), which represents agricultural productivity. Regardless of the values reached by this variable every year, the behavior was similar between varieties, with slight differences of White Call variety compared to the others. The values of this index were higher in 2011 plantation, but the pattern of behavior was similar in both years, when Spunta variety reached the lowest values.

It was interesting that Call White variety showed a marked increase of this indicator at the end of crop cycle, which is logical when considering that it reached the highest yield in both years (data not shown).

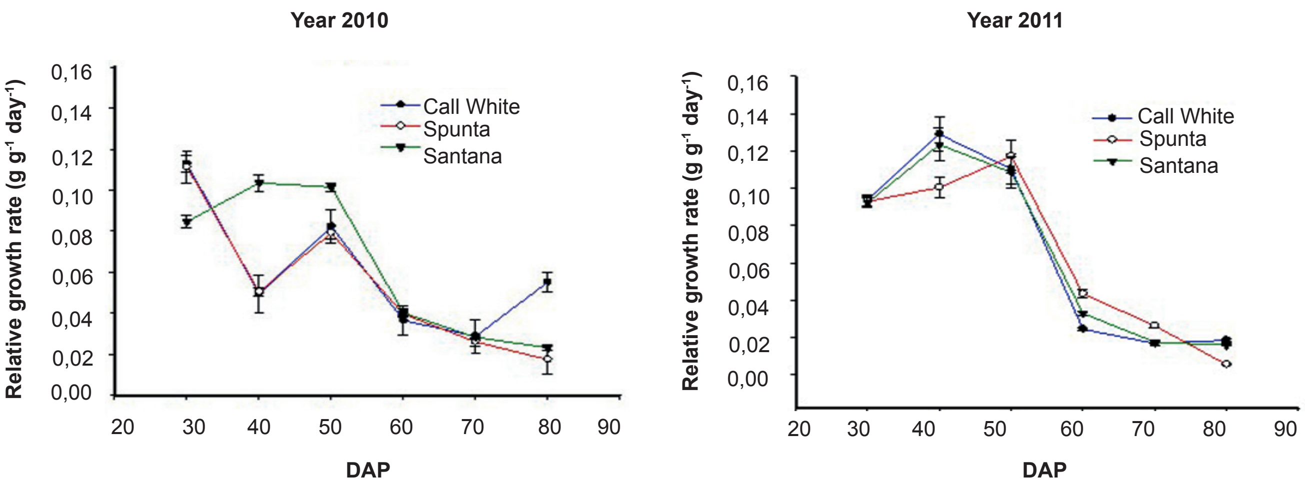

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Figure 4. Behavior of Relative Growth Rate (RGR) in three potato varieties planted in 2010 and 2011

On the other hand, when vegetative growth rate decreases and tubers start filling (17), if there is any foliage reduction, generally caused by biotic factors (presence of fungal diseases or others), then yields decrease, although it has been tested that stem density does not affect total leaf area nor potato dry mass production (18).

Figure 6 presents Source Power (SP) related to the behavior of assimilative organs (NAR). Values of this variable were higher in 2011 planting and growth pattern was similar in both years, except in Spunta variety, which was out of phase when it reached the maximum value in the second plantation.

The highest values recorded in 2011 plantation could be related to a lower demand from storage organs (tubers), so that there is less assimilate translocation to those organs and a consequent yield reduction (19).

Moreover, the fact that there are higher LAI values at the plantation of 2010, along with lower NAR and SP values denote deficiencies in the use of photosynthetically active radiation to produce more assimilates.

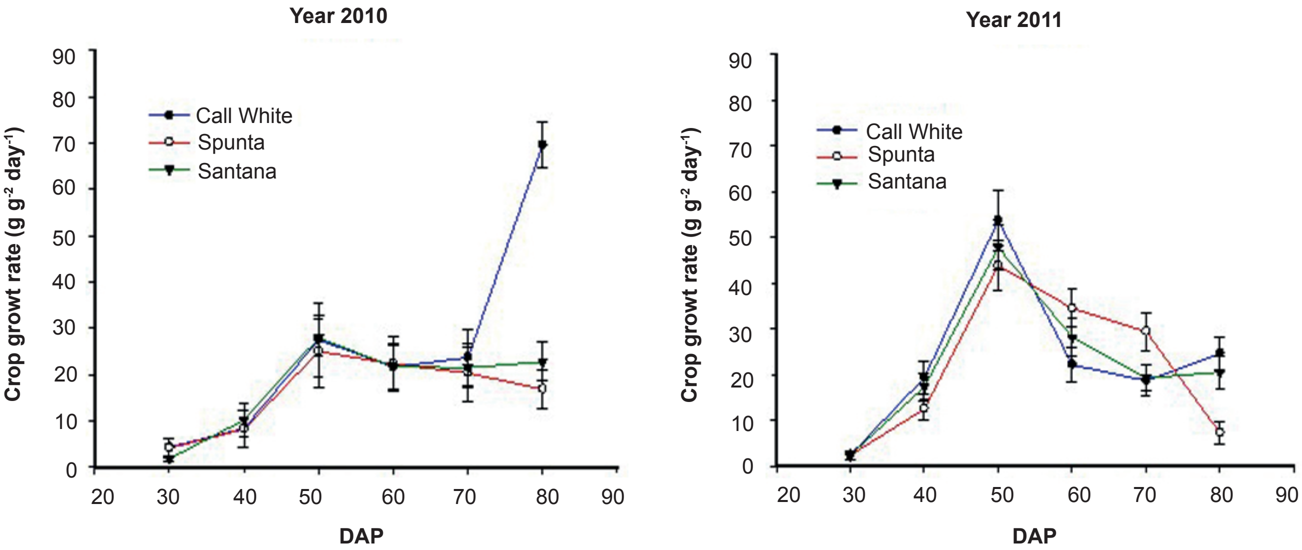

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Figure 5. Behavior of Crop Growth Rate (TCC) in three potato varieties planted in 2010 and 2011

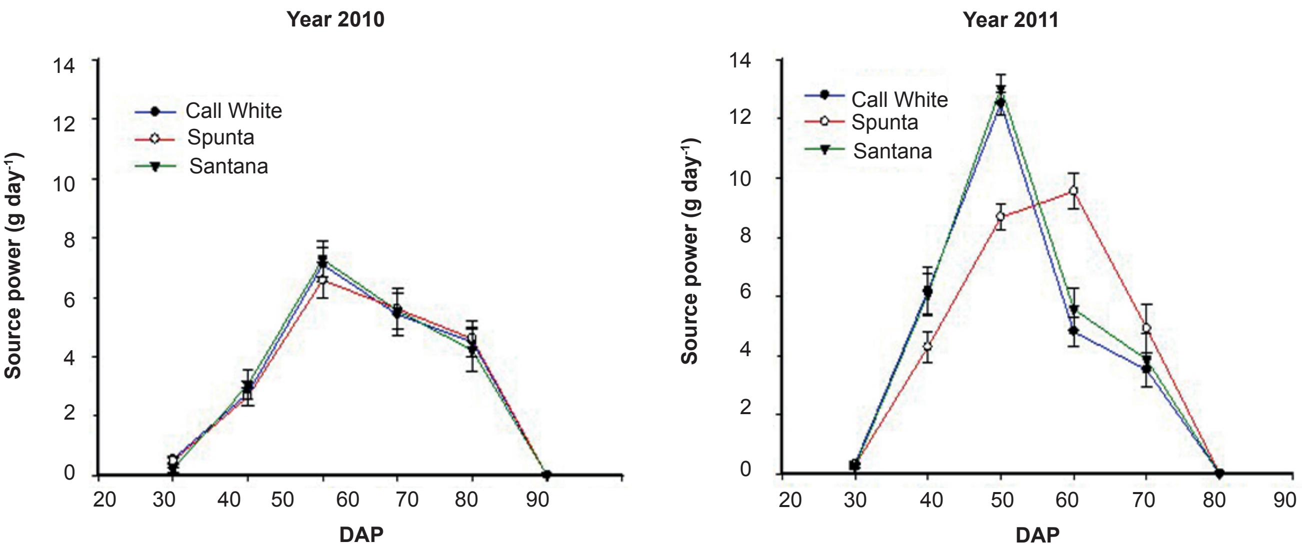

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Figure 6. Source Power (SP) in three potato varieties planted in 2010 and 2011

Source power decreases over time and is associated with less photosynthetic activity, thereby, with biomass reduction (20), as it occurs in other crops; leaf shape and an adequate nitrogen fertilization also influence this aspect (21, 22).

When analyzing Demand Power (DP), as shown in Figure 7, there were lower values at the plantation of 2010, with a different pattern of behavior to that observed in 2011, when this variable increased, with a subsequent quantity decrease.

This behavior was largely related with NAR, which ensures that in the way assimilates are produced by assimilative organs, they will be exported to consumption or storage sites.

If considering that on average, LAI was lower in the plantation of 2011, it would be possible to suggest that demand power (tubers) had a greater value in that year. On the other hand, the efficiency of photosynthetically active energy conversion into dry mass should be noted, on which tuber storage time under environmental conditions and its quality will depend, without being severely damaged (23).

Total dry mass accumulation is faster within 40-100 days after planting, corresponding to the beginning of tuber formation and development; at the end of the season, tubers record up to 90 % total dry mass (24).

Some of these indexes are not only important to interpret growth based on the influence of different abiotic factors, but also for its use in models to simulate the behavior of growth and its effect on yields (25).

It is necessary to keep in mind that potato tuber formation depends on assimilate availability and tuber ability to accumulate them; however, it depends on source capacity (26).

Finally, it should be noted that a rapid increase of tuber dry mass presupposes NAR increase to ensure such behavior, but it is not always the case; this variable was able to reach minimum values at the end of crop cycle, which indicated yield reduction and it is associated with the interception of solar radiation, something that should be evaluated in future works, if considering that the optimal leaf area rate supports the maximum dry mass rate, that is achieved when the crop intercepts all photosynthetically active radiation; however, as crop cycle is very short under tropical conditions, these requirements are not always met.

CONCLUSIONS

Differences on the evaluated indexes are denoted among varieties, but crop cycle was similar in them, so it will depend on each physiological efficiency to achieve high yields. LAI and NAR behavior was interesting, mainly because the latter clearly depends on the former.

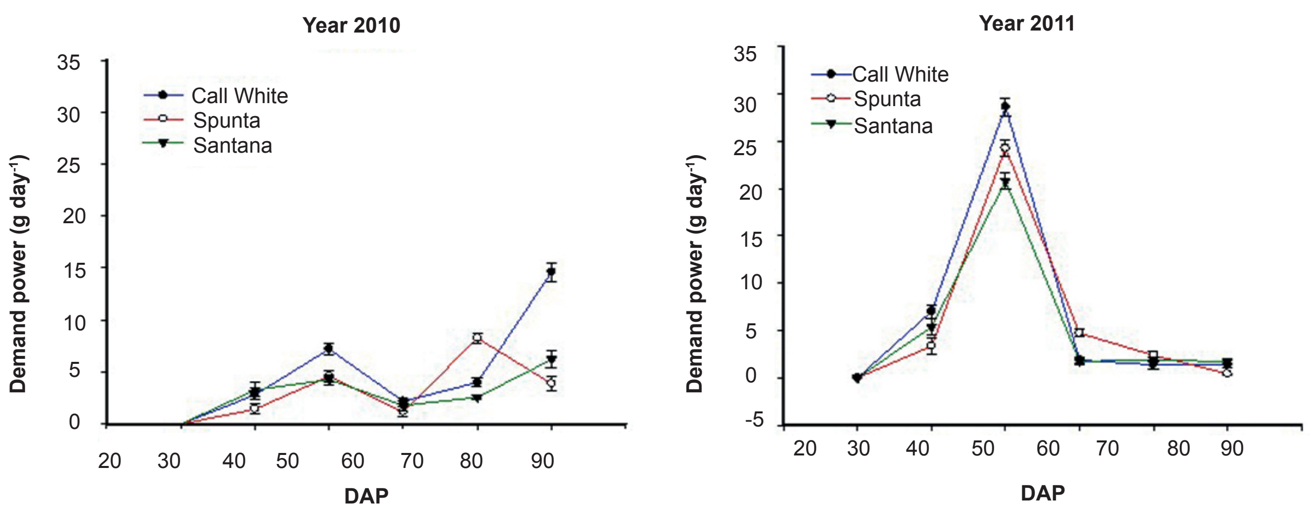

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Figure 7. Demand power in three potato varieties planted in 2010 and 2011

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