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INFLUENCE OF THREE SOWING DATES ON THE BIOLOGICAL PRODUCTIVITY OF SORGHUM CULTIVATION (*Sorghum bicolor* L. MOENCH)

Influencia de tres fechas de siembra sobre la productividad biológica del cultivo del sorgo (*Sorghum bicolor* L. Moench)

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ABSTRACT. In order to evaluate the influence of three planting dates on growth and supply demand relationship in the cultivation of sorghum, the work was developed at the National Institute of Agricultural Sciences (INCA). Three planting dates were studied: November 2008, June 2009 and July 2009, using a density of 15 kg ha^{-1}. Plants destructive samplings were made every 15 days after emergence to harvest, determining the dry mass of organs, adjusting the data to a polynomial exponential function of the second degree, "x" was the days after the emergency "y" variable in question. From the regression equations the net assimilation rate (NAR) and leaf area ratio (RAF) were calculated. The relationship between the power source and power demand was also calculated and found to greater efficiency in the use of radiation leads to higher maximum in (NAR) and the potential between the supply and demand organs and therefore a greater accumulation of biomass in next time to physiological maturity, standing out in this case the dates of June and July 2009 which expressed more efficient in relation to growth rates assessed behavior, resulting in these higher yields.

Key words: dry matter content, productivity, yield

RESUMEN. El trabajo se desarrolló en el Instituto Nacional de Ciencias Agrícolas (INCA), con el objetivo de evaluar la influencia de tres fechas de siembra sobre el crecimiento y la relación fuente-demanda en el cultivo del sorgo. Se estudiaron tres fechas de siembra: noviembre de 2008, junio de 2009 y julio de 2009, utilizándose una densidad de 15 kg ha^{-1}. Se realizaron muestreos destructivos cada 15 días de emergidas las plantas hasta la cosecha, determinándose la masa seca por órgano. Los datos se ajustaron a una función exponencial polinómica de segundo grado, "x" fue los días después de la emergencia y "y" la variable en cuestión. A partir de las ecuaciones de regresión se calcularon la tasa de asimilación neta (TAN) y la relación de área foliar (RAF). También se calculó la relación entre la potencia de la fuente y la potencia de la demanda. Se encontró que una mayor eficiencia en el uso de la radiación conlleva a valores máximos más elevados en la (TAN) y en los potenciales entre los órganos fuente y demanda y por tanto a una mayor acumulación de biomasa en momentos próximos a la madurez fisiológica. Se destacaron en este caso las fechas de junio y julio de 2009; las cuales manifestaron un comportamiento más eficiente en relación con los índices de crecimiento evaluados, obteniéndose en estas los mayores rendimientos.

Palabras clave: contenido de masa seca, productividad, rendimiento

INTRODUCTION

Sorghum (*Sorghum bicolor L*. Moench) is one of the cereals that due to its agronomic and nutritional characteristics could bring great benefits in human and animal food, worldwide, tropical and national (1).

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In conditions of low soil moisture, sorghum maintains a physiological activity similar to that of plants with sufficient moisture by increasing root length, density and efficiency of water use. Its biomass is used in various ways for the production of energy, fiber or paper, as well as syrup in several regions.

This crop is well adapted to Cuba conditions which showed an incipient development that disappeared in parallel to the collaboration of the CAME (Council of Mutual Economic Assistance).

Today there is no wide tradition and experience in terms of production; however, different tests indicate that the yields are satisfactory and that they could be increased if there were appropriate and sustainable technologies that allowed them to express their full potential (1).

The yield of a crop depends on its capacity for growth and the assimilate production and on what part of it allocates to the organs of economic interest. The growth results from the use of sunlight in the manufacture of the constituent and functional components of the different organs of the plant. Therefore, it is directly related to the ability of the cup to capture incident light. The modification consequences of the implantation moment of the crop on its growth result from the incidence of temperature, radiation and photoperiod on its phenology, the development of the foliar area and the accumulation of dry matter (2).

In the cultivation of sorghum, it is stated that the yield of the grain is determined almost totally by the mobilization of assimilated product of the laminar photosynthesis carried out during the stage of filling the seed, that is, the post-anthesis stage. The contribution of pre-anthesis laminar photosynthesis is an important factor, since it contributes up to 12 % of seed yield (3). Therefore, the productivity of crops is governed by complex interactions between climate and the ecophysiological processes that these entail. The productive success depends not only on the intensity of the climatic stimuli but also on the temporal sequence of these during the life cycle of the crops (2).

The photosynthetic efficiency of the cultivated plants and the total production can be determined through the use of growth indexes, which indicate the effectiveness of the plants to take advantage of the environmental factors and the way in which they distribute their assimilates (4). Therefore, the objective of this work was to evaluate the influence of three sowing dates on growth and the demand source relation of sorghum cultivation.

MATERIALS AND METHODS

The work was developed in the experimental area of the National Institute of Agricultural Sciences (INCA), located in San José de las Lajas, Mayabeque, located at 138 m a.s.l. Three sowing dates were established: November 18th, 2008, June 12th, 2009 and July 31st, 2009, on a Red Ferralitic soil (5), following the recommendations for crop production (6). In sorghum variety "ISIAP Dorado", a sowing density of 15 kg ha^{-1} of seed was used. Weekly and after 15 days after the emergency (DAE) the following indicators were determined by destructive sampling:

Leaf area index (LAI): for this the leaf area was estimated by the disk method based on dry mass.

Dry grain yield: the data of the growth indicators were adjusted to a polynomial exponential function of the second degree, calculated from this, the dry mass by organs, the net assimilation rate (NAR) of the dry mass and the ratio of leaf area (RLA).

Additionally, the strength or power of source and demand of each sowing date was determined throughout the crop cycle, using the formulas proposed by Castellanos and collaborators (7).

Power of the source = Size of the source (Foliar Area) * Source activity (NAR)

Demand power = Size of demand (dry matter spike) * Demand activity (TRC spike)

The average air temperature data was taken from the Tapaste meteorological station, next to the experimental site, not taking into account the rainfall data since it was applied to irrigation whenever it was required (Figure 1).

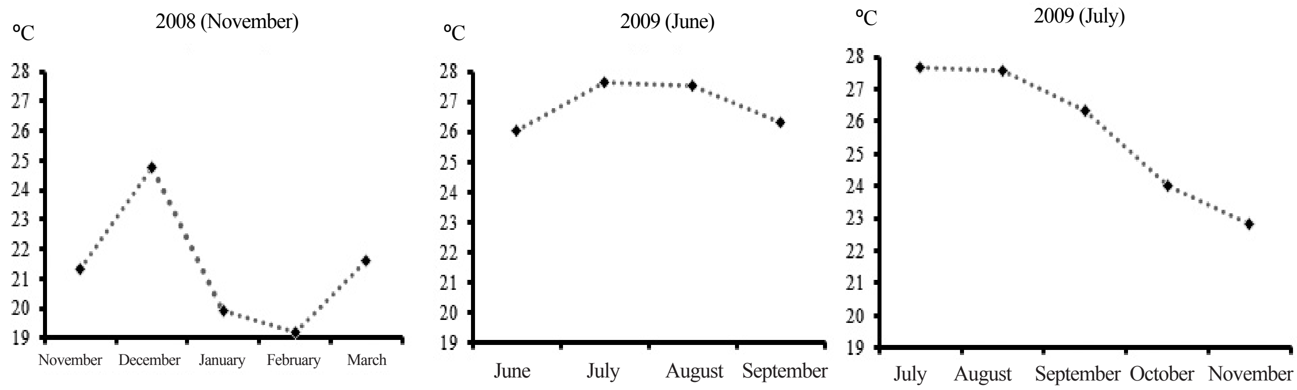

Figure 1. Behavior of temperatures during the three sowing dates

RESULTS AND DISCUSSION

Figure 2 indicates the dynamics of growth of the dry mass by organs of the aerial part in the sowing dates studied. As for the accumulated dry mass of the leaves, the highest values were obtained on the sowing date of July 2009 with a maximum value of 389,2 g m^2 at 100 days after the emergency, continued from the date of November 2008 which achieved the maximum accumulated at 75 days with a value of 319,9 g m^2 and sowing June 2009 with a maximum cumulative of 306, 6 g m^2 at 87 days. These maximum values reached coincided with a phenological stage of the plants for each planting date, which correspond to the physiological maturity (July 2009), the anthesis (November 2008) and the massive state of the grain (June 2009). In this way the sowing dates of June and July 2009 showed maximum leaf development in a phenological stage closer to the harvest.

The accumulated dry mass curves of the stems show that the highest accumulated ones are presented at the sowing dates of June and July 2009 with 809, 1 g m^2 and 734, 9 g m2, respectively. These maximum values were obtained in stages closer to the harvest compared to the November 2008 planting, as shown in the table of maximum values. It is proposed that the biophysical processes that control the production of aerial biomass and the yield of crops at a potential rate are the amount of solar radiation absorbed by vegetation and the use of this energy in plant growth (8).

On the other hand, the accumulated curves of dry mass of the spikes show that at 83 and 96 days the maximum values reached corresponded to the sowing dates of July and June 2009 with 842,4 g m^{-2} and 813,1 g m^{-2}, respectively, followed by the sowing date of November 2008.

The results obtained could be given by the behavior of the temperatures during the period in which the experiments were carried out. Well during the sowing dates of June and July 2009, dates in which maximum values of accumulated dry mass were obtained, the temperature data reported were higher than those reached during the entire crop cycle compared to the planting date of November 2008 (Figure 1). If we take into account that sorghum is considered a warm climate plant that responds to high temperatures and the optimum for its development is between 29 and 30 ºC; due to its morphological characteristics, since it presents a good growth of the root system, with a low level of transpiration in relation to the high capacity of root absorption and a waxy cover in the stems and leaves that make it a very efficient crop in such conditions (9-11).

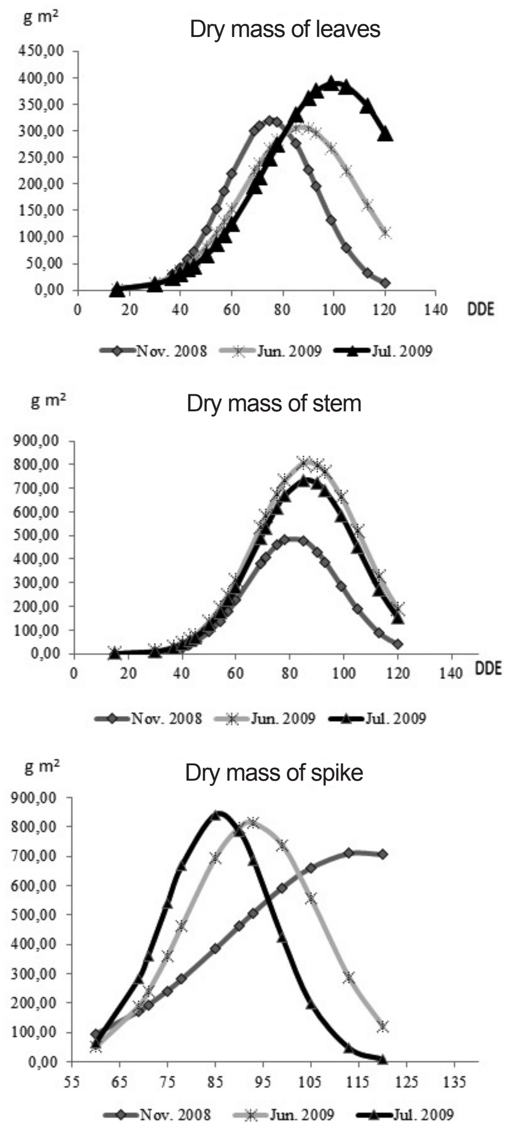

Figure 2. Behavior of the dry matter by organs in each of the sowing dates

The accumulation of dry matter in a vegetable is a process that, in addition to the internal factors of the plant, governed in this specific case by the behavior of photosynthesis and respiration, also depends to a large extent on the external (environment) (12).

The total dry matter production is the result of the foliage efficiency of the crop in the interception and use of solar radiation available during the growth cycle. However, this efficiency may be influenced by the amount of solar radiation, the ability of the leaves to photosynthesize, the index of leaf area, the architecture of the plant, respiration, among others; This is summarized in internal growth factors related to the genotype and external factors related to the environment and management practices used during the cycle (13-15).

As stated (12), in a plant the number of leaves is determined genetically and it has been assumed that the speed of the foliar increase given by the number of leaves present at some point and the development they achieve, will be directly dependent on the increase of temperatures.

The net assimilation rate (NAR) is a measure of foliage efficiency, which is the main source of photoassimilates for dry matter production. This index records the speed of net photosynthesis in a period of time, and the change in the values of the leaf area and the dry weight of the plant must be known (16). Figure 3 shows the behavior of the NAR, which presented the highest values up to 45 days after the emergence in the three sowing dates, because the plants were at the beginning of the vegetative stage. Different authors (17,18), expressed that the NAR shows higher values in the first stages of development of the plant, a stage in which there is greater exposure to total radiation, a condition that is contrary in the most advanced stages of plant growth.

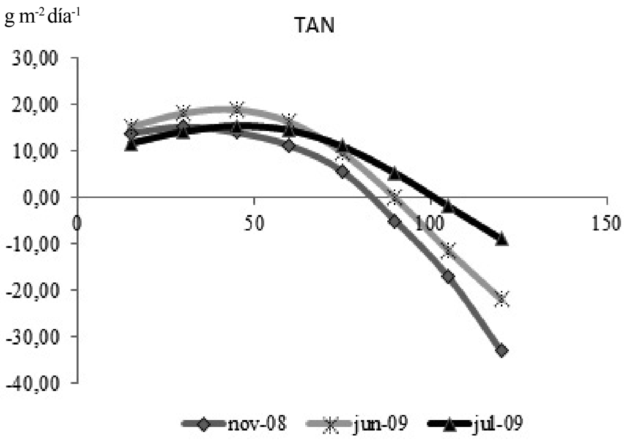

Figure 3. Behavior of the net assimilation rate in three sowing dates

After reaching the maximum values, the NAR decreased (after 45 days) in the three sowing dates; however, the minimum values were obtained first on the dates of November 2008 and June 2009 at 90 days after the emergence and at 105 days these values were reached for the sowing of July 2009. The foregoing indicates that for on this planting date, the plants showed that the photosynthetic efficiency was maintained for a longer period of time. According to studies carried out, it is proposed (19) that each species responds in a particular way to the radiation stimuli it receives from the environment, these responses being different even within the same species in different physiological stages of development.

Similar results to this study were reported in another investigation (20), finding in the 'Río Grande' variety of tomato a higher NAR in the first stages of development of plants exposed to total radiation, a condition that became contrary in the more advanced states of growth.

Thus, studies conducted showed that tubers of potato (*Solanum tuberosum* L.) for seed reached a maximum value of NAR (10 gm^{-2} d^{-1}) (21), despite being a species with C^3 metabolism, when they grew with 100 % of radiation during the entire crop cycle, and decreased in plants that grew with 40 and 70 % incident radiation.

A decrease in the NAR after reaching the maximum point could be given, due to the increase in the age of the leaves together with the self-shading of the lower leaves of the plant, thus reducing the photosynthetic efficiency. In this sense it is proposed (22) that the reduction of NAR with development is due to decreases in photosynthetic rates rather than to the increase in respiratory losses of the plant.

Observing the results obtained it can be seen that the sowing date of June 2009 presented higher values in the NAR which were reached in the phenological phase of crop formation. The sowing of July 2009 was located with intermediate values, which were obtained in the spike formation phase and at the last extreme, with a lower NAR, the date of November 2008, in which its maximum photosynthetic efficiency corresponded to the phenological phase of formation of the eleventh leaf. These variations in the photosynthetic efficiency between dates could be due to the environment, which can be verified from the behavior of the temperatures presented during the experiments. On the other hand, as stated, the temperature and radiation intercepted for the conditions of Cuba, during the months of June and July coincide with the maximum values (23).

From the above it is derived that the dates that showed maximum values of NAR, achieved higher production of air dry matter in moments closer to the harvest and that this was maintained in the same way for a longer period of time; which translates into greater photosynthetic efficiency. In studies carried out in the cultivation of corn, they state that the total dry matter production is the result of foliage efficiency in the interception and use of solar radiation available during the growth cycle (24).

Figure 4 reaffirms the criteria proposed above, since the leaf area ratio (RAF) is presented in the three sowing dates, which is a measure of the balance between potential photosynthetic capacity and potential respiratory cost. In the same it can be observed that during the first stages of growth, the plants reached the maximum values in this indicator for all sowing dates, which could indicate a maximum potential photosynthetic capacity (25), they gradually diminished as that the age of the crop advanced. The decrease in the values of RAF as the sorghum advances in age is normal, since in the first stages of growth, the plants invest a large amount of their photoassimilates in the conformation of their vegetative structure, reversing this relationship when it is established the reproductive phase (26).

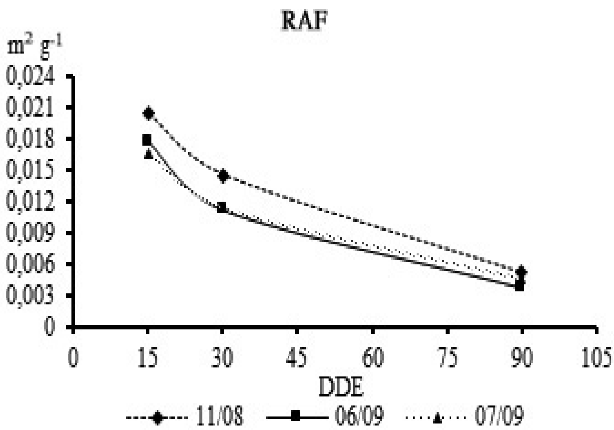

Figure 4. Behavior of the leaf area ratio on three planting dates

Planting in November 2008 presented the highest RAF values during a large part of the crop cycle; however, the dates of June and July 2009, reached lower values. These results are given due to the behavior of the temperatures which during the last two planting dates the plants were exposed to higher temperatures and therefore higher incident radiations, the opposite happened on the date of November 2008. This indicates that the low radiations stimulated an increase in the leaf area ratio in the plants.

Likewise, in the three sowing dates a progressive decrease of this indicator is observed, since as it is proposed (27), the decrease in the values of RAF as the age of the crop advances is normal, since in the early stages of growth the plants invest most of photoassimilates in the establishment of their foliar apparatus; this amount gradually decreases as the plant accumulates a greater amount of carbohydrates in other organs of the plant.

The amount of solar radiation absorbed by vegetation and the use of this energy in plant growth constitute the biophysical processes that control the production of biomass and the yield of crops at a potential rate (7).

The results obtained from the determination of source and demand potentials are shown in Figure 5. It shows that the sowing dates of June and July 2009 reached a power from the higher source and in a phenological state more advanced than the sowing of November 2008 which may show that these sowing dates showed a greater efficiency of their photosynthetic apparatus in a stage closer to the yield formation.

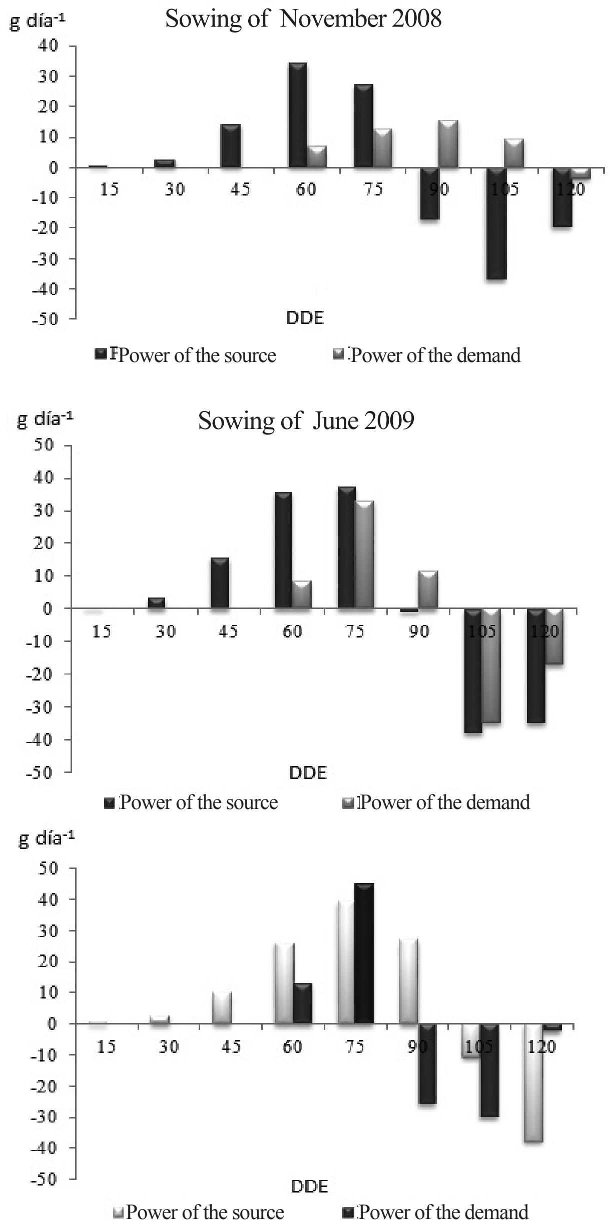

Figure 5. Behavior of the demand source relation in the three sowing dates

Similarly, the power of the demand shows a behavior similar to that of the power of the source for the sowing dates, as shown in said figure. The sowing date of June and July 2009 reached the maximum values at 75 days after the plants emerged with 32,9 and 44,9 g day^{-1}, with the latter reaching a higher value than the previous one. The sowing of November 2008 presented the maximum power of the demand at 90 days with a value of 15,46 g day^{-1}. The production of assimilates by the leaves and the point at which accumulation occurs, which in this case is represented by the organs that are harvested, has a significant influence on crop yield (28).

As evidenced by the results obtained, between the sowing dates there is a different behavior in terms of the power of the demand bodies, coinciding for the dates of June and July 2009 with the maximum power of the source, showing these dates a greater ability of the organs to demand assimilated, which may be related to rapid cell division and expansion, which is reflected in a linear phase of dry matter accumulation of the plant's source organs. This process implies a greater phloematic discharge of photoassimilates in this landfill tissue and therefore greater strength as "demanding" tissues of carbohydrates and other organic substances (7).

Therefore, it is expected that the sowing dates evaluated have periods in which the values of source power and demand power are very similar, indicating equivalent skills to produce assimilated in the leaves and to obtain them in the spikes. In the case of the sowing dates of June and July 2009, these were submitted to the 75 days where the greatest potential source and demand were obtained, while on the date of November 2008 it occurred in the corresponding period of 75-90 days after the emergency. As it is stated, this phenomenon has implications at an agronomic level if one takes into account that a decrease in the foliar area caused by phytosanitary problems can result in low source power, which can lead to low yields (7).

As can also be seen in the aforementioned figure, on the sowing date of June 2009, after 75 days, it was observed that the source power in this time interval is lower compared to the demand power; even, the foliage is in the senescence stage in this period of the crop cycle, so it is presumed the possibility of a temporary storage in the stems before the final accumulation of assimilated by the spike, in the final stage. In addition, a feature of several plants that has been raised previously (29) is the ability to temporarily store photosynthetic metabolites and nutrients in tissues along the transport path between the source and the demand, remaining available for later use in the plant either because the demand increases or because the availability of photoassimilates is reduced at a given time.

Regarding the performance behavior (Figure 6) it is important to mention that there are differences in the sowing dates, those dates that showed a more efficient behavior of the photosynthetic apparatus; as well as, higher cumulative dry mass had higher yields, which may be due to the fact that during these dates there were more favorable conditions for the growth and development of the plants and therefore a higher productivity; especially due to the behavior of the temperatures throughout the crop cycle, which were more favorable during the sowings of June and July 2009, in this sense as it is stated (11) that sorghum is a crop considered to be very efficient in regarding environmental conditions.

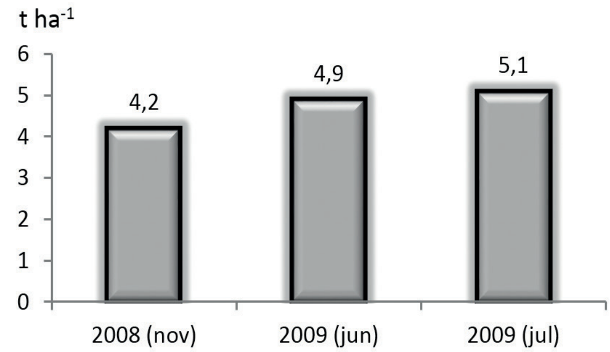

Figure 6. Performance behavior on the three planting dates

It is important to point out that during these dates higher maximum values of NAR were shown, as well as in the potentials between the source and sink organs, so that the conditions that occur during the crop cycle and the state reached during its establishment and especially in a phase closer to physiological maturity will imply higher yields.

The relation between the total biomass and the economic yield has been studied in the different agricultural crops, in addition to the general form, it is emphasized that the higher the production of total dry matter, the higher yield, so it is emphasized that the distribution of dry matter within of the plant plays an important role in determining performance (15).

From the two main performance components, the number of grains is the most sensitive to environmental variations and to the availability of components such as radiation, temperature, water and nutrients in the soil; while the grain weight is more stable and depends mainly on the source/demand ratio during the period of grain filling (30).

Agronomic management practices have an important role in determining the final yield in the corn crop, as it is the sowing date, because it can significantly modify the duration of the ontogenic cycle and the ability to capture solar radiation; this impacts dry mass production and grain yield (31).

CONCLUSIONS

According to the results obtained, it should be noted that the yields in the sorghum crop were influenced by the sowing date and the maximum values were in correspondence with a higher efficiency in the use of incident solar radiation which led to higher values in the net assimilation rate (NAR) and in the potentials between the source and sink organs and therefore to a greater accumulation of biomass at moments close to physiological maturity.

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