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DRY MATTER ACCUMULATION IN DIFFERENT ORGANS OF THE RICE PLANT (*Oryza sativa* L.) AND ITS RELATIONSHIP TO GRAIN FILLING IN THE DRY SEASON

Acumulación de masa seca en los diferentes órganos de la planta de arroz (*Oryza sativa* L.) y su relación con el llenado de los granos en la época poco lluviosa

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ABSTRACT. With the objective of evaluating the dry matter accumulation in different organs in four rice cultivars and its contribution to grain filling this work was developed in Scientific and Technological Basic Unit from "Los Palacios". The cultivars INCA LP-5, Reforma, INCA LP-2 and J-104 were used and they were sowed over a Ferruginous Nodular Gley Petroferric soil in December of 2004, February of 2005 and January of 2006. The direct sowing technology was employed. Plant breeding activities were developed as recommended by Rice Crop Technical Instructive. A Randomized Blocks Experimental Design with four replications was carried out. The distribution of the dry mass of different organs of the main stem in 25 plants per plot was evaluated and the agricultural yield at 14 % of grain moisture was determined. The data matrix obtained was processed by principal components multivariate techniques and the relationship between yield and the variables more associated was determined by a regression analysis. The results showed that the second and the third internode of the rice plants main stems are considered the highest contribution photoassimilates reserve organs to the grain filling, besides the dry mass content of these organs in anthesis could be considered by breeders as an important element for selecting cultivars with high yield potential.

Key words: rice, dry matter content, yield, growth

RESUMEN. El trabajo se desarrolló en la UCTB "Los Palacios", con el objetivo de evaluar la acumulación de masa seca en diferentes órganos de la planta de arroz y su contribución al llenado de los granos en cuatro cultivares. Se emplearon los cultivares INCA LP-5, Reforma, INCA LP-2 y J-104, los cuales se sembraron en diciembre del 2004, febrero del 2005 y enero del 2006 sobre un suelo Hidromórfico Gley Nodular Ferruginoso Petroférrico. Se empleó la tecnología de siembra directa y las actividades fitotécnicas se desarrollaron según lo recomendado por el Instructivo Técnico del Cultivo del Arroz. El diseño experimental fue de bloques al azar con cuatro réplicas. Se evaluó la distribución de la masa seca de diferentes órganos del tallo principal en 25 plantas por parcela y se determinó el rendimiento agrícola al 14 % de humedad del grano. La matriz de datos obtenida fue procesada por las técnicas multivariadas de componentes principales y se determinó la relación entre el rendimiento y las variables más asociadas mediante un análisis de regresión. Teniendo en cuenta los resultados se puede concluir que el segundo y tercer entrenudos del tallo principal en plantas de arroz se consideran como los órganos de mayor contribución de fotoasimilados de reserva al llenado de los granos y que el contenido de masa seca en estos órganos en el momento de la antesis pudiera ser considerado como un elemento a tener en cuenta por los mejoradores para la selección de cultivares con posibilidades de alto potencial de rendimiento.

Palabras clave: arroz, contenido de materia seca, rendimiento, crecimiento

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INTRODUCTION

The grain filling is a process that determines the performance and final phase in cereal growth, where the fertilized ovaries are developed in caryopses (1).

Its duration and filling rate determine the grain final mass that is an essential component that contributes to the total plant yield. In rice cultivation, the filling stage has been a process characterized by changes in nonstructural carbohydrates metabolism such as sucrose and starch (2). According to the findings by some authors who have studied cereals, plant organs, source and sink, are active in this process, where the grain filling can be limited by the plant photosynthetic activity (the source) and grain absorption capacity (the sink), or a combination of both (3, 4, 5).

Therefore, reserve carbohydrate metabolism has been examined in different plant organs such as leaf sheaths, flag leaf and stem in various stages of ripening grain. This has allowed to emphasize the distribution and the involvement of accumulated carbohydrate in these organs in the filling (6); so in production systems, it has been given a vital crop management function of grain filling (7), given that this process depends on carbohydrates arising from two main sources, the treated fresh synthesized directly transported to grains and assimilated stored and distributed to the reserve organs from vegetative tissues (2).

However, it is noteworthy that contribution analysis of assimilated stored in the reserve organs of vegetative tissues to grain filling is relatively complex (8). For example, if one considers the stems, it must be assumed that they occupy an intermediate position between the main source organs and the ones are considered as sink, making it even more complicated when the analysis takes into account differences in capabilities storage and mobilization of reserves among internodes. Given the above, this work was developed with the objective of evaluating the dry mass accumulation in different rice plant organs and its contribution to grain filling in four cultivars in the dry season.

MATERIALS AND METHODS

The work was carried out in areas of STBU (scientific and technical base unit) “Los Palacios”, Pinar del Rio, and part of the National Institute of Agricultural Sciences. Two short cycle cultivars (INCA LP-5 and Reform) they were used and two half-cycle cultivars (INCA LP-2 and J-104), which were planted in the dry season (planting dates December 2004, February 2005 and January 2006) on a Hydromorphic Ferruginous Nodular Gley Petroferric soil[A] Direct sowing technology was used, with a standard planting 120 kg ha^{-1}. The phytotechnical activities were developed as recommended by the Technical Instructions rice cultivation[B]. The experimental design was randomized blocks with four treatments and four replications to each one, with experimental plots 25 m^2. For photoassimilates contribution to grain filling distribution of the different organ dry mass of the main stem was evaluated. For these five representative plants per plot they were taken for all treatments in each sampling time (anthesis, 10 and 20 days). In order to make these determinations, they were marked the heading beginning 25 plants per plot for each treatment (9).

To each main stem selected in different sampling times, their organs were separated: panicle (P) flag leaf (FL), leaf sheath (LSh), remaining leaves present on the stem (H) and the top three intenodes (first internode (Int 1), second internode (Int 2) and third internode (Int 3), plus the peduncle (Ped.). These samples were dried in an oven for 72 hours at 70 °C to constant weight and then were weighed on an analytical balance.

In the middle of the data were determined and confidence interval were plotted for analysis. Agricultural yield 14 % grain moisture, data were processed by analysis of variance dual classification and the averages compared by Tukey test at 5 % probability of error is also determined.

The confidence interval was determined for the data average and they were plotted for analysis Agricultural yield at 14 % grain moisture is also determined, data were processed by an analysis of double classification variance and the averages compared by Tukey test at 5 % probability of error.

The data matrix obtained was processed by Principal Component multivariate techniques by representing a Biplot and autovectors, in order to determine the association degree among variables at the time of anthesis with yield. Then, the relationship between yield and more variables associated thereto by a regression analysis was determined.

RESULTS AND DISCUSSION

Dry mass variations of each internode of the main stem body (internode 3, internode 2, internode 1 and peduncle) of rice plants in four studied cultivars for different planting dates shown in Figure 1.

[A]Hernández, A. J.; Ascanio, G. M.; Morales, Marisol y León, A. La historia de la clasificación de los suelos en Cuba. Editorial Félix Varela. La Habana 2006. pp. 49-54.

[B]IIArroz. Instituto de Investigaciones del Arroz. Instructivos técnicos del arroz. Cuba- MINAGRI, 2001. 43 pp.

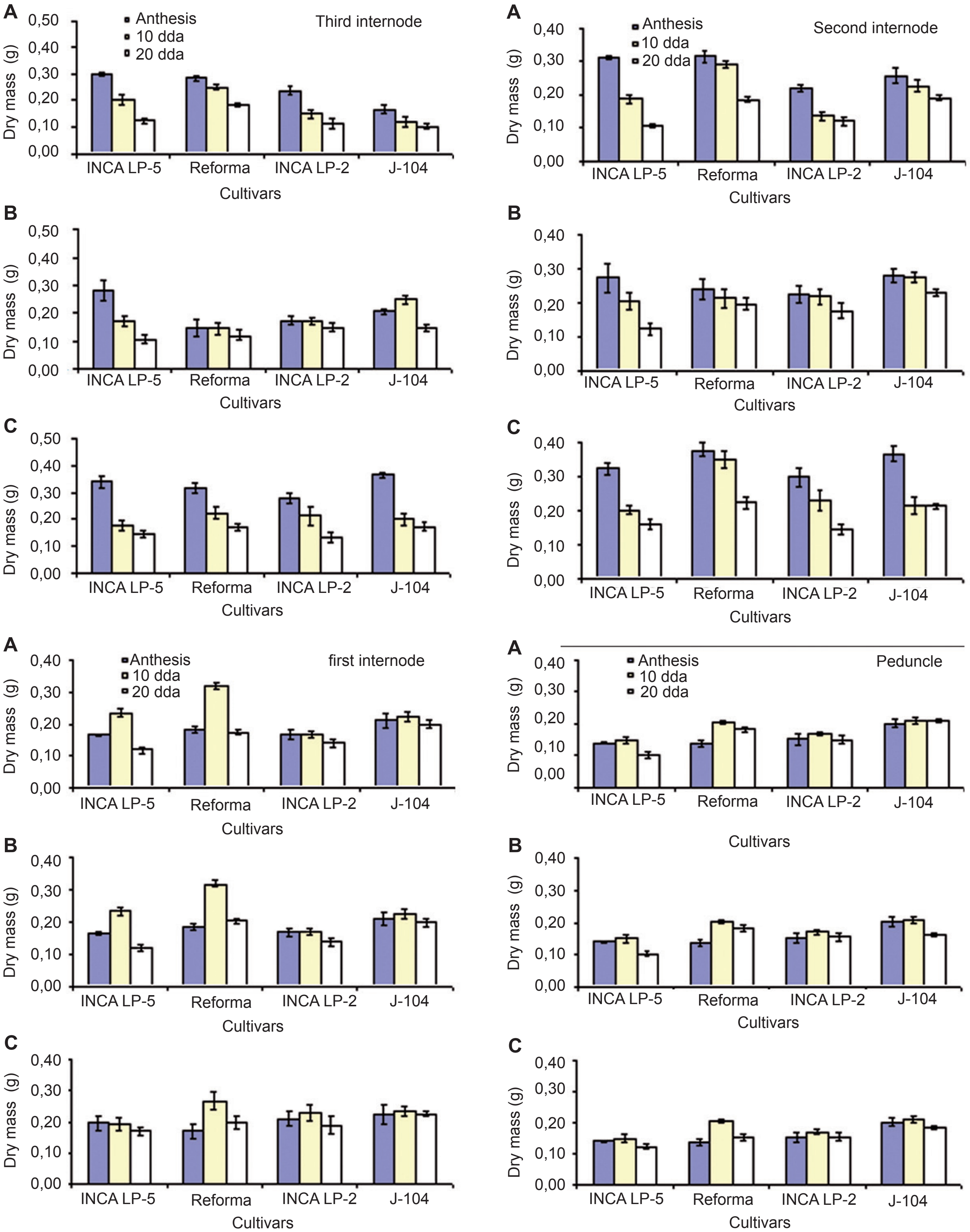


Figure 1. Dry mass (g) of the third, second, first intenodes and peduncle in the main stem of rice cultivars in three stages of grain filling, in three planting dates during the dry season (A) in December 2004 (B) in February 2005 (C) in January 2006

During the grain filling period, anthesis to maturity, the behavior of biomass accumulation in the top of the main stem and the peduncle was different for each of cultivars in different planting dates.

In the case of third internode a decrease in dry mass is observed from anthesis to 20 days after anthesis (daa) for all cultivars planting dates in December 2004 and January 2006. In February 2005 only INCA LP-5 cultivar showed a decrease in this variable unlike Reform LP-2 and INCA cultivars dry mass remained constant throughout the period; and J-104 cultivar increased from anthesis until 10 daa was observed to decrease until 20 daa.

A similar behavior is observed in the second internode dry mass in different cultivars for different planting dates. Though, in the case of the first internode (Figure 1) short-cycle (INCA LP-5 and Reform) cultivars in all planting dates show an increase in the dry matter from anthesis until 10 daa then declined, only INCA LP-5 cultivar in January 2006 remains very similar values throughout the period, showing behavior much like the half cycle (INCA LP-2 and J-104) cultivars in all mounted experiments.

As for the peduncle, it should be note that there are differences between cultivars regardless of planting date. In the INCA LP-5 cultivar for all dates studied, the dry mass remains relatively constant from anthesis until 10 daa then declined; unlike Reform cultivar from anthesis begins increased dry mass to 10 daa then declined. However, half cycle cultivars show a very similar behavior to that found when evaluating the first internode.

Considering everything observed in Figure 1 should be noted that in the third and second internodes regardless of cultivar and planting date, is basically where the highest values of accumulated dry mass are observed (over 80 % of cases exceeded 25 g) in addition it is in these two organs which affords a greater reduction of the dry mass from anthesis to 20 daa (about 75 % of cases decreases the variable 50 % of what was achieved in the anthesis). This shows that the two bodies behave as sinkholes of photoassimilates temporary storage before flowering; similar results were obtained by other authors (10). Other authors (8), observed in rice plants starch content increase in the stem, before the process of anthesis and others point out that, dry matter maximum values and especially of the starch content were reached at the flowering date (6).

In the case of pods, dry mass decreasing was influenced by planting date (Figure 2), this behavior is only seen in dates December 2004 and January 2006. As for the flag leaf blade, dry mass values remained constant throughout the period and leaf blades, there is no defined pattern of this variable behavior. The panicle dry mass increased significantly from anthesis until 20 daa, short cycle INCA LP-5 and Reform cultivars had higher dry matter in panicle than half cycle INCA LP-2 and J-104 cultivars.

The size increasing in the product sink to a higher dry mass in panicle could be the cause of the dry mass decrease in different organs above mentioned, especially in the second and third internode product to the photoassimilate mobilization (11). In this sense, we must highlight the INCA LP-5 cultivar since each planting date, dry mass values and loss of the same at 10 and 20 daa usually exceeds the rest of cultivars.

In assessing agricultural yield (table) can be appreciated that, in general, the best performances reached short cycle compared to half cycle, something that has been highlighted by other authors emphasizing the superiority in performance in certain rice cultivars with precocious cycle (12, 13, 14) although the planting date of January 2006 there were no differences between cultivars must also note the INCA LP-5 cultivar with 6 t ha^{-1} in all experiments, which can be related to what was argued earlier in this paper on the storage and carbohydrate movement which has this cultivar.

On the date of January 2006 was where the highest values of this variable were obtained without significant differences among cultivars and is at this time where one can see a further dry mass decrease in the third and second internodes from anthesis to 20 daa, something that could have influenced higher activity of grain filling for all cultivars, which could be related to the weather conditions may have favored the process.

Agricultural yield behavior (t ha^{-1}) at 14 % moisture grain and rice cultivars, planted in dry season

Cultivars	Yield (t ha^{-1})		
	December 2004	February 2005	January 2006
INCA LP-5	6,2 a	6,0 ab	6,2 a
Reforma	6,1 a	5,5 bc	6,1 a
INCA LP-2	5,5 bc	4,8 d	5,6 abc
J-104	5,3 cd	5,3 cd	5,7 abc
ESx		0,07	
CV		8,34	

Mean treatments with different letters differ significantly p<0,05, n=4

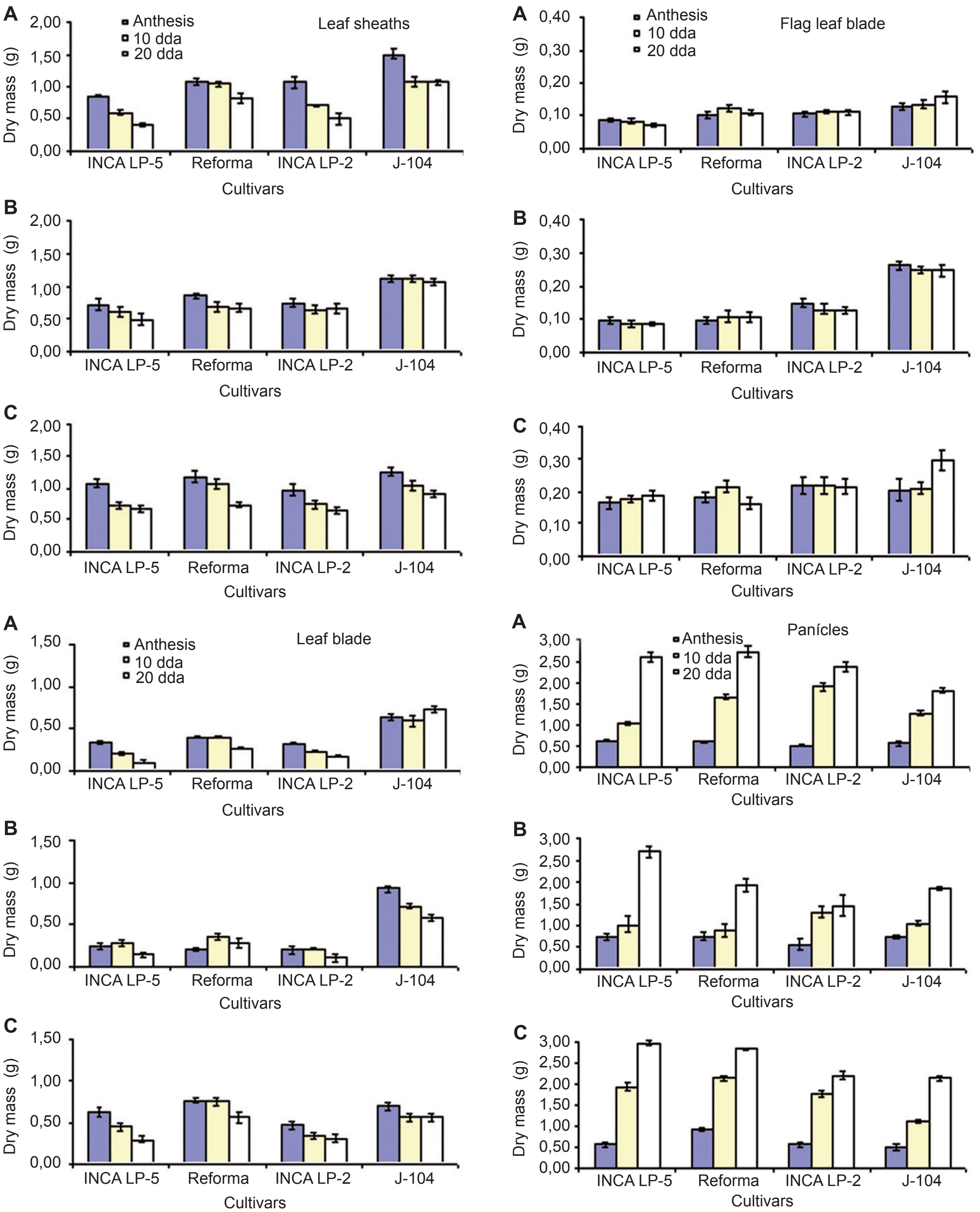
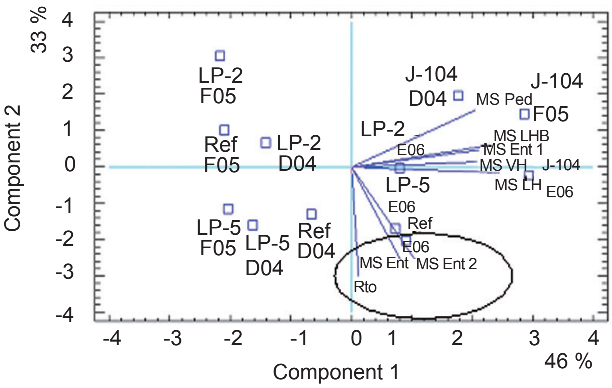


Figure 2. Dry mass of leaf sheaths, the flag leaf blade, the rest of the leaves blade and the main stem panicle of rice cultivars in three stages of grain filling and in three dates planting during the dry season; (A) in December 2004; (B) in February 2005; (C) in January 2006)

To determine the dry mass loss by internodes and other parts of the plant might be attributed to mobilization of photoassimilates to the grains during filling and therefore emphasize their influence on the crop yield results are taken into account Biplot analysis for both sowing (Figure 3). Main components 1 and 2 accounted for 46 and 33 % respectively of the total variability, meaning that these two main components explain a high percentage (79 %) of the total variation in behavior. of these physiological variables



D04, Ja06 and F05, planting dates: December 2004, February 2005 and January 2006; LP-5, Ref, LP-2, J-104 INCA LP-5, Reforma, INCA LP-2 and J-104 cultivars; DM Int 1, DM Int 2; DM Int 3, Ped DM, DM LSH, DM LB, DM FLB is the dry mass of intenodes 1 2.3, from peduncle, leaf sheaths, the leaf blade and the flag leaf blade respectively of the main stem in rice plants)

Figure 3. Distribution of original variables obtained at anthesis of the three planting dates set on the first and second component in the dry season

As shown in Figure 3 the greatest association with yield was given by the third and second internodes dry mass at the anthesis time. From this result we can infer that both organs are the most prone at grain filling with a considerable yield formation in rice cultivation under the dry season conditions in Cuba.

Considering the dry mass association of the second and third performance internodes, a relationship between them was established (Figure 4), where a coefficient of about 0.80 was obtained showing a good fit from the mathematical point of view performance, so the yield was positively related to dry mass of these organs at the anthesis time. This could be an aspect to be considered by breeders at the time selection of cultivars with high yield potential, since cultivars achieve greater dry matter accumulation in their internodes would have greater availability of photoassimilates that would be an important alternative source of carbohydrates for grain filling in the culture, especially when still continues to work on increasing the throughput capacity at precocious cultivars (15).

In this regard, studies by some researchers (8) emphasizes that the availability of photoassimilates present in internodes differs according to their position on the stem, and the third internode could be a key source of reserve carbohydrates for grain filling.

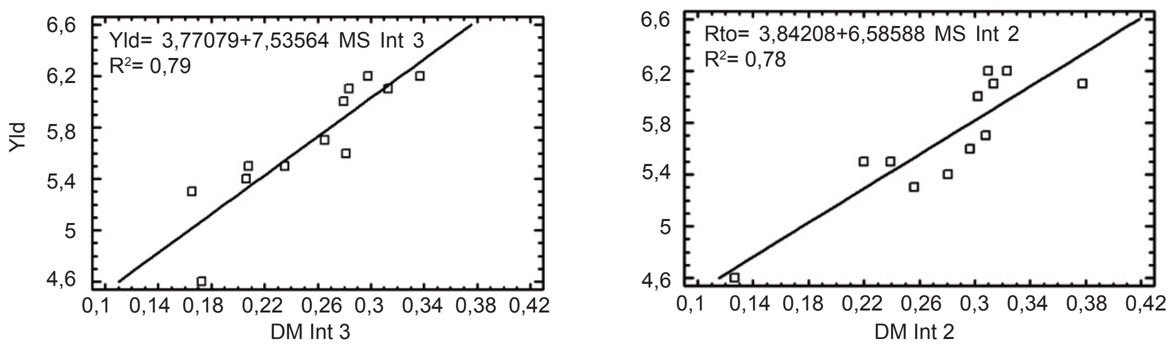


Figure 4. Relationship of the dry mass (g) of the second and third internode from the main stem of four rice cultivars at the anthesis time and agricultural yield 14 % grain moisture (t ha-1) n=12

CONCLUSIONS

Taking into consideration results it can be concluded that the second and third internodes of the main stem in rice plants are considered as organs greatest contribution of photoassimilates reserve at the grain filling and dry mass content in these ones, the anthesis time, it could be considered as an element by breeders to select cultivars with odds for high yield potential.

BIBLIOGRAPHY

1. Takai, T.; Fukuta, Y.; Shiraiwa, T. y Horie, T. Time-related mapping of quantitative trait loci controlling grain-filling in rice (*Oryza sativa* L.). *Journal of Experimental Botany*, 2005, vol. 56, no. 418, pp. 2107-2118. ISSN: 1460-2431.
2. Yang, J. y Zhang, J. Grain filling of cereals under soil drying. *New Phytologist*, 2006, vol. 169, pp. 223-236. ISSN: 1469-8137.
3. Hernández Córdova, Naivy y Soto Carreño, Francisco. Determinación de índices de eficiencia en los cultivos de maíz y sorgo establecidos en diferentes fechas de siembra y su influencia sobre el rendimiento. *Cultivos Tropicales*, 2013, vol. 34, no. 2, pp. 24-29. ISSN: 1819-4087.
4. Hernández Córdova, Naivy y Soto Carreño, Francisco. Influencia de tres fechas de siembra sobre el crecimiento y rendimiento de especies de cereales cultivadas en condiciones tropicales. Parte I. Cultivo del maíz (*Zea mays* L.). *Cultivos Tropicales*, 2012, vol. 33, no. 2, pp. 44-49. ISSN: 1819-4087.
5. Yang, J. y Zhang, J. Grain-filling problem in super rice. *Journal of Experimental Botany*, 2010, vol. 61, no. 1, pp. 1-5. ISSN: 1460-2431.
6. Cuéllar, N. D. y Arrieta, J. M. Evaluación de respuestas fisiológicas de la planta arbórea *Hibiscus rosasinensis* L. (Cayeno) en condiciones de campo y vivero. *Corpoica Cienc. Tecnol. Agropecu.*, 2010, vol. 11, no. 1, pp. 61-72. ISSN: 0122-8706.
7. Polón Pérez, Ricardo; Castro Alvarez, Rodolfo; Ruiz Sánchez, Michel y Maqueira López, Lázaro A. Práctica de diferentes alturas de corte a cultivo de rebrote y su influencia en el rendimiento del arroz (*Oryza sativa* L.) en una variedad de ciclo medio. *Cultivos Tropicales*, 2012, vol. 33, no. 4, pp. 59-62. ISSN: 1819-4087.
8. García, A.; Dorado, M.; Pérez, I. y Montilla, E. Efecto del déficit hídrico sobre la distribución de fotoasimilados en plantas de arroz (*Oryza sativa* L.). *Interciencia*, 2010, vol. 35, no. 1, pp. 54. ISSN: 0378-1844.
9. Nagata, K.; Yoshinaga, S.; Takanashi, J. y Terao, T. Effects of dry matter production of non structural carbohydrates and nitrogen application on grain filling in rice cultivar Takanari, a cultivar bearing a large number of spikelets. *Plant Production Science*, 2001, vol. 4, no. 3, pp. 173-183. ISSN: 1349-1008.
10. García, A.; Dorado, M.; Pérez, I.; Cun, R.; López, T. y Montilla, E. Acumulación de biomasa seca en diferentes órganos de la planta de arroz en condiciones de déficit hídrico. *Agronomía Tropical*, 2009, vol. 59, no. 1, pp. 15-24. ISSN: 0002-192X.
11. Ralph, A.; Assol, D.; Magalhães, A.; Costa, A. y Bacarin, M. Crescimento e partição de arroz diferindo no potencial de productividade de grãos. *Bragantia Campinas*, 2009, vol. 68, no. 3, pp. 563-571. ISSN: 1678-4499.
12. Acevedo, Marco, A.; Salazar, M.; Castillo, W.; Torres, O.; Reyes, E.; Navas, M.; Alvarez, R.; Moreno, O. y Torres, E. Efectos de la densidad de siembra y fertilización nitrogenada sobre el rendimiento de granos de arroz del cultivar centauro en Venezuela. *Agronomía Tropical*, 2011, vol. 61, no. 1, pp. 15-26. ISSN: 0002-192X.
13. Acevedo, Marco A.; Castillo, W. y Torres, O. Estabilidad fenotípica de arroz de riego en Venezuela utilizando los modelos LIN-BINNS y AMMI. *Agronomía Tropical*, 2010, vol. 60, no. 2, pp. 131-138. ISSN: 0002-192X.
14. Morejón, Rogelio y Díaz, Sandra H. Combinación de las técnicas estadísticas multivariadas y el diseño aumentado modificado (DAM) en la selección de líneas de prueba en el programa de mejoramiento genético del arroz (*Oryza sativa* L.). *Cultivos Tropicales*, 2013, vol. 34, no. 3, pp. 65-70. ISSN: 1819-4087.
15. Atencio, V. J.; Berrío, L. E.; Borrero, J. y Carabalí, S. J. Producción eco-eficiente del arroz en América Latina. Tomo I. Publicación CIAT No. 370. Cali, Colombia: Imágenes Gráficas S.A., 2010. 487 pp. ISBN: 978-958-694-103-7.

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