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ACCUMULATION AND DISTRIBUTION OF DRY MASS BEHAVIOUR IN THREE VARIETIES OF POTATO (*Solanum tuberosum* L.)

Comportamiento de la acumulación y distribución de masa seca en tres variedades de papa (*Solanum tuberosum* L.)

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ABSTRACT. The work was developed in the experimental areas of the National Institute of Agricultural Sciences during plantations carried out in the month of January of the years 2010, 2011 and 2012, with the aim to evaluate the distribution and accumulation of dry mass behaviour among different organs of the plant. Tubers seeds of three potato varieties (*Solanum tuberosum* L.) Call White, Santana and Spunta, planted in three parcel(one for each variety) following a design sample. At 40 and 70 days after the plantation and in the crop, were carried out samplings of 10 plants at random for each variety, to know by means of drying in stove the quantity of dry mass in the different organs. During the cycle of the cultivation were registered the stockings, maximum and minimum temperatures present in that period. Differences between varieties were detected in the magnitude of the values reached in the accumulation of dry mass, even when the three follow the same patron of growth. Could be notice that at beginning of the plantation the demand for dry mass is much bigger in the foliage, it is invested toward the tubers at the end of the same one. The influence of the temperatures in the growth was discussed; it has a big influence in the dry mass production.

Key words: varieties, growth, assimilates source, assimilates demand, temperature

RESUMEN. El trabajo se desarrolló en áreas experimentales del Instituto Nacional de Ciencias Agrícolas (INCA) durante plantaciones realizadas en el mes de enero de los años 2010, 2011 y 2012, con el objetivo de evaluar el comportamiento de la acumulación y distribución de masa seca entre los diferentes órganos de la planta. Se utilizaron tubérculos semillas importados de tres variedades de papa (*Solanum tuberosum* L.) Call White, Santana y Spunta, plantadas en tres parcelas (una por cada variedad) siguiendo un diseño muestral. A los 40 y 70 días después de la plantación y en la cosecha, se muestrearon 10 plantas al azar por cada variedad, para conocer mediante secado en estufa la cantidad de masa seca en los diferentes órganos. Durante el ciclo del cultivo se registraron las temperaturas medias, máximas y mínimas ocurridas en ese periodo. Se detectaron diferencias intervarietales en la magnitud de los valores alcanzados en la acumulación de masa seca, aun cuando las tres siguen un mismo patrón de crecimiento. Se destaca que al inicio de la plantación la demanda por masa seca es mucho mayor en el follaje, lo cual se invierte hacia los tubérculos al final del mismo. Se discute la influencia de las temperaturas en el crecimiento en general, lo cual se reflejó en la producción de masa seca.

Palabras clave: variedades, crecimiento, fuente de asimilatos, demanda de asimilatos, temperatura

INTRODUCTION

The accumulation of dry mass is usually used as an important indicator in the studies to characterize plant growth and it has a great economic significance. Depending on the objective, potato cultivars can be selected based on this indicator (1); the assimilate production by the leaves and the point in which the accumulation occurs, represented in this case by the harvested organs (tubers), has a significant influence on crop yield. The coordination between crop growth and development is important, as well as the dry mass distribution (2).

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A study of the distribution pattern of dry mass among the organs of the plant, is important for the evaluation of the growth rate, productivity and yield. The metabolism of the source and the demand site are closely coupled because the information on the availability of each organ is perceived and used to make up the expression of genes involved in this process which is a necessary coordination to avoid wide fluctuations and unbalances between supply and demand (3).

The assimilation of dry matter and its distribution within the plant, are important processes that determine the productivity of the crop. The study of the allocation patterns of dry mass towards different parts of the plant, the variability of these patterns among cultivars and the and the effects of the environmental conditions prevailing in the process, can help to maximize productivity and select cultiviars for a specific purpose, even when potato has a wide adaptability to different agroecological conditions (4, 5).

The presence of plant organs with a net demand for assimilates, can strongly influence the production and distribution patterns of dry mass, it is mainly regulated by the power of the demand organs (6). Moreover, there are reports indicating that the assimilates distribution among demand sites, is mainly regulated by themselves, even when regardless the conditions where plants develop (7), more than 50 % of the dry mass produced is accumulated.

Taking these premises into account, this research was done to evaluate the behavior of dry mass accumulation in three potato varieties, which could be an important indicator to consider in breeding programs.

MATERIALS AND METHODS

The trial was conducted in experimental areas of the National Institute of Agricultural Sciences (INCA), following a random design. Plantings were done in the first two weeks of January 2010, 2011 and 2012, on a Eutric Compacted Ferralitic Soil (8), using imported seed tubers above 45mm, of the varieties Call White (from Canada), Spunta and Santana (from Holland) spaced at 0,30x0,90m (one plot of 252 m^2 per variety). These varieties represented at that time, an important volume among those used by the country in the different growing sites.

Cultural practices were applied according to the Tecnical Guidelines for this crop (9) including irrigation that in this case was done with a Central Pivot sprinkling machine. As long the trials stayed under field conditions, maximum, minimum and mean temperatures were recorded by the Weather Station close to the experimental site; data from the three variables were processed every ten days.

Using destructive sampling of 10 plants per variety, the different plant organs were separated: roots, stems and leaves, they were oven-dried at 80^0C till constant mass to reach the actual dry mass. For tubers, the percentage of dry mass percentage was determined and from the fresh mass and the former variable, the accumulated dry mass was determined. These determinations were done 40 and 70 days after planting (DAP) and at harvest time. The first two moments are related to the initial growth rate of the tubers (40 DAP) and the start of their maturity (70 DAP).

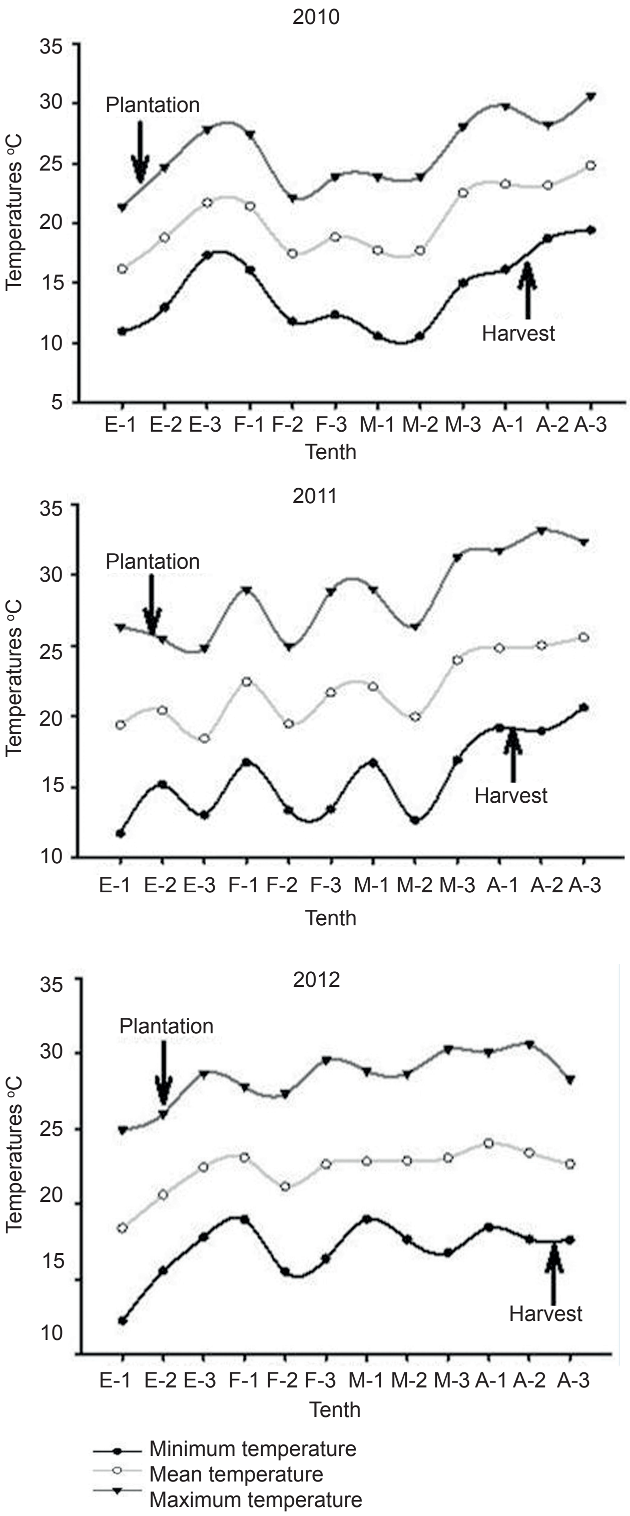
Based on the total accumulated dry mass values for leaves and tubers, in each of the evaluated moments, the relative growth rate for this variable in both organs, was calculated. From the total dry mass per plant, the percentage represented by each organ was estimated taking into account the average of the three years studied.

Total dry mass data per plant at each evaluated moment were processed through ANOVA and in the case of the growth rate calculation for the accumulated dry mass in leaves and stems, the standard error of the means was determined by using, in both cases, the Statistical Software Statgraphics version 5.0 (10).

RESULTS AND DISCUSION

Figure 1 illustrates the behavior of maximum, minimum and mean temperatures during the three years of the trial.

Though the behavior of the value range attained every year were similar, in the year 2010 maximum temperatures showed lower values that kept longer under that condition, while low temperatures were much higher in 2012, compared to the rest of the years. The first condition favored the development of the crop and allowed it to reach a higher dry mass yield than in the rest of the evaluated years, it will be discussed further ahead. Temperatures and photoperiod have been pointed out as the most important climate factors influencing on potato growth and development (4).



The arrows in the figures identify the plantation and momentum, respectively

Figure 1. Behavior of maximum, minimum and mean temperatures (every ten days) during the growing period in the three evaluated years (arrows identify planting and harvest, respectively)

Temperatures in 2010 were favorable during tuber growth, appropriate for their formation and development (18-22 ^{0}C). As can be seen in the recorded means for the years 2011 and 2012, they surpass those established as optimum (11) since they range from 15 to 20 ^{0}C, though some varieties yield the maximum with temperatures above (12), which is not the case of those used in this trial.

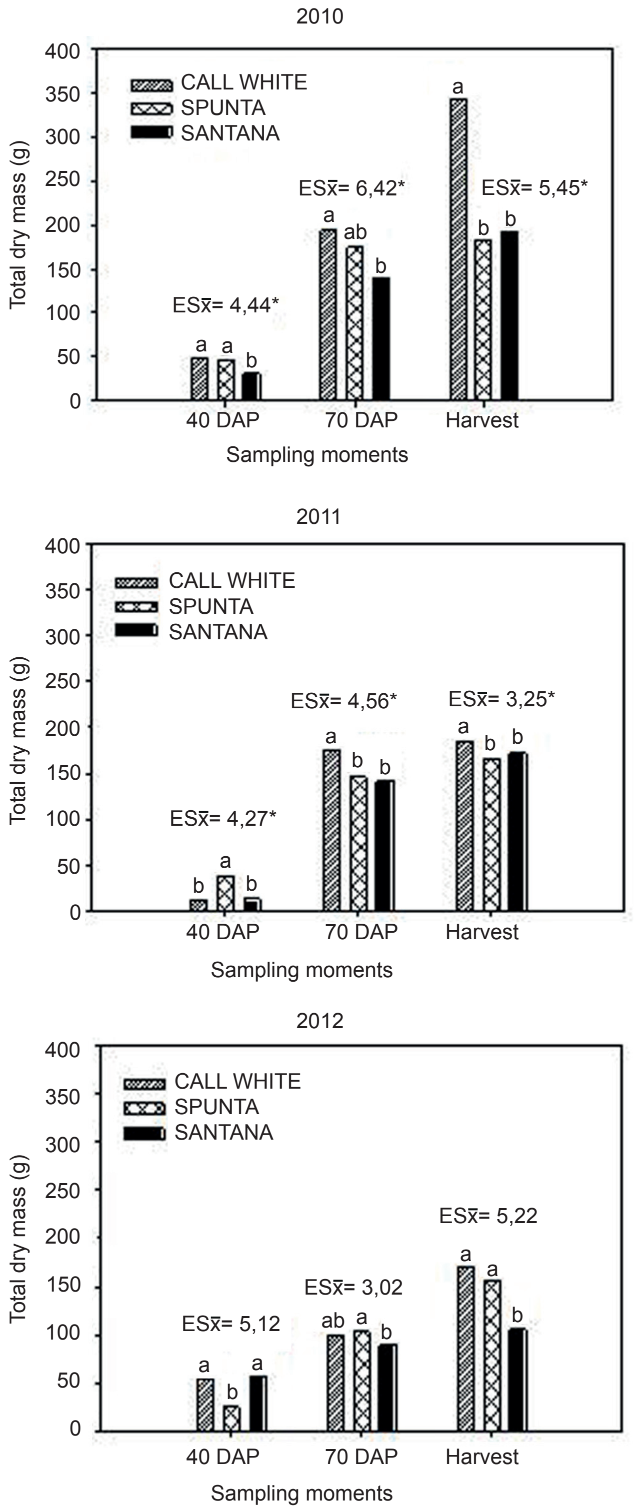
On the other hand, it is said (13) that quick temperature variations, as happened in the years 2011 and 2012 compared to 2010, affected the general behavior of the crop which results in lower yield and reduced dry mass production in general. Likewise, it has been pointed out (14) that the multiple interrelation established among climatic elements and potato plants, will greatly depend on the general production of the plot.

In this behavior the crop cycle plays a very important role, though it was not analyzed, it was higher for all varieties in 2010, compared to the other two years. This, in turn, favored an increased biomass production as will be discussed further ahead. It has been shown the damage caused in the dry mass distribution in potato genotypes due to the behavior of the effective degree-days (15), but it should also be said that high temperatures during planting affect yields (16) in tropical areas.

When analyzing the total biomass accumulation in each of the sampling moments (Figure 2) significant differences were detected among varieties and in general, the largest accumulation was found in the variety Call White with differences compared to the other two.

These results fully comply to the accumulation rates found for each variety, but each year was different behavior wese, which could be influenced by climatic conditions, which in fact, were different each year, as happened to temperatures.

The cultivar Call White showed a sustained increase in dry mass accumulation in the years 2010 and 2012, but not in the 2011, unlike Spunta, in which this behavior was only recorded in 2012. Such behavior denotes multiple interactions that take place between the internal factors of the plant and those of the environment (14). It is reflected on a great variability among varieties as well as on the reached values. In this regard, there have been differences among cultivars which is mainly due to the efficiency of each of them as to dry mass accumulation is concerned, as well as for its distribution and the power between the assimilate source and the demand site for it (3).



Means with different letters are significatively different at p≤0,05

Figure 2. Accumulation of total dry mass (g) at different sampling moment of each studied year

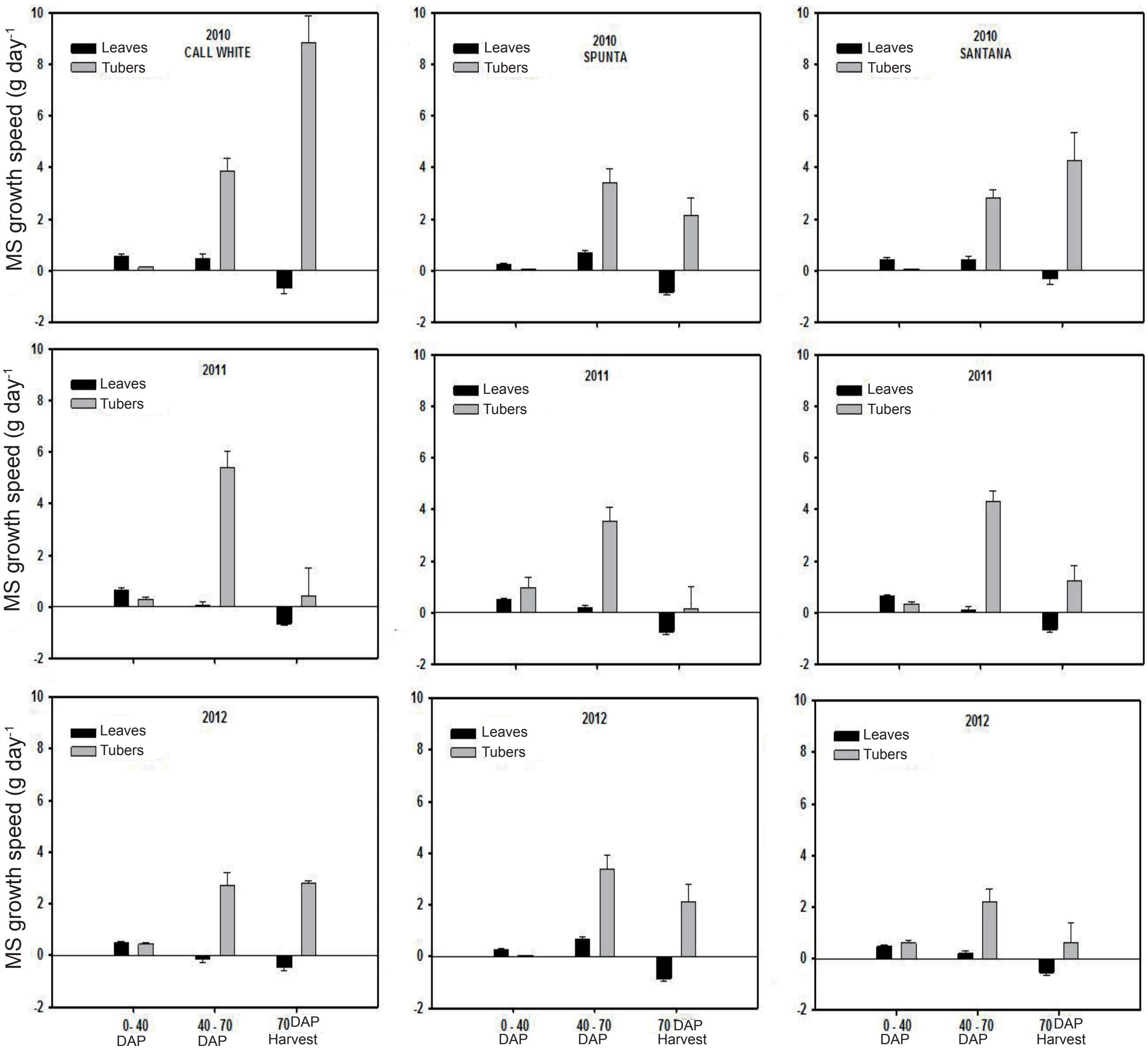
The total dry mass production is the result of the foliage efficiency in catching and using the sun light available during growth (3). However, this efficiency can be influenced by the quantity of sunlight, the leaf ability to photosinthesize, the foliar area index, plant's arquitecture and respiration, among others; all of which can be summarized in the participation of internal growth factors related to the genotype (17) and those external factors related to the environment, as well as the cultural practices implemented during the cycle (18, 19).

In practice, the concentration of drymass produced in tubers (20) is a useful index that defines tubers quality and the use that could be made of them for different purposes (21).

Figure 3 shows the dry mass growth rate for leaves and tubers at different moments.

There were significative differences all the time between the organs producing dry mass (source), in this case leaves and the demand site for assimilates (tubers) which show the highest growth rates. In general, the period from 40 to 70 DAP is where the highest accumulation rate is reached. There are differences with the variety Call White, for which planting made in 2012, exhibited negative growth rates in leaves in that period. It is indicative that growth was much more accelerated till that time than in the rest of evaluated varieties. This behavior also caused that different growth stages were reached faster thus standing out as a much earlier variety than the others.

At the end of the cycle, leaves showed negative growth rates which differ from their reduction in plants due to the senescence process. For this reasons, plants' capacity to produce biomass in this period is also reduced which influence that in this time a lower export and accumulation of dry matter towards storage sites (tubers) be produced, since the most part has already been translocated to those sites. This behavior explains what happens in studies related to defoliation. When leaf fall takes place later, plants' yield is not so much affected because most of the biomass accumulation in tubers has already taken place (22).



The confidence interval for the means in each bar is also shown, p<0,05

Figure 3. Relative growth rate of dry mass of leaves and tubers at different intervals of the crop cycle for the studied varieties and years

The proportional biomass accumulation (Figure 4) showed a similar tendency to the three studied varieties, but a lower accumulation of biomass in leaves and stems, will guarantee a higher proportion to the tubers (storage sites). It was evident for varieties like Call White and Santana, to have a higher translocation. It has been confirmed that even when varieties follow a similar growth pattern converning dry mass accumulation, these differ in the capacity of producing it (23) and it is noticeable that stems and leaves, after tubers, are the most accumulating organs. It is necessary to emphasize that the efficiency in translocating assimilates to the tubers depends on the varieties used (24) and this, in turn, will define the quality of the tuber (25).

The Spunta variety showed the higher root percentage which did not favor the increased dry mass of tubers, unlike the other two evaluated varieties that showed the lowest values. The demand exerted by the tubers in this variety was lower than in the other two because under equal conditions, there was a higher dry mass percentage in leaves, compared to the total produced during the crop cycle. In stems also, the percentage was slightly higher, which indicates that the mobility of assimilates from leaves and stems towards tubers, was lower in this variety.

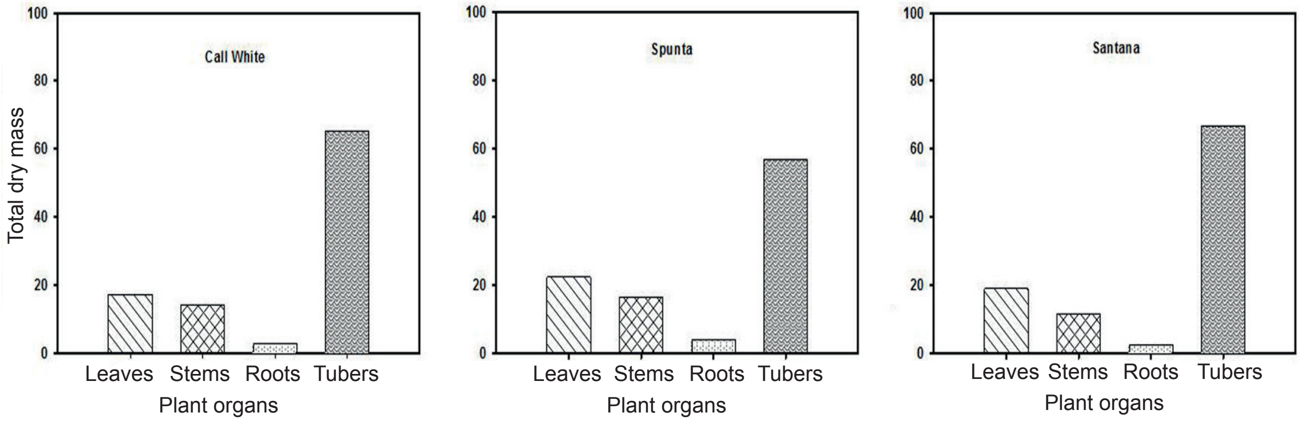


Figure 4. Percentage distribution regarding total dry mass by organs in four potato varieties

As it can be seen, the percentage distribution as per the growth pattern, showed very little variations. The Spunta variety stood out for having a differentiated behavior to the other two (higher percentage in leaves and lower percentage in tubers), a factor influencing the growth cycle of the crop and supposing superb attention of the agronomical management (2) relative to foliage care against *Phytophtora infestans*, since, if it shows up in early growth stages, important damages to yields can occur.

On the other hand, the fact of finding different behavior patterns in the used varieties, does not exclude the need to continue deepening on this type of study, because different external factors influence the accumulation and distribution of the dry mass, something in which climatic factors should not be disregarded, if it is considered that their variations are due to the climate change effect (26, 27).

BIBLIOGRAPHY

1. Fernandes, A.M.; Soratto, R.P. y Pilon, C. ‘‘Soil Phosphorus Increases Dry Matter and Nutrient Accumulation and Allocation in Potato Cultivars’’, *American Journal of Potato Research*, vol. 92, no. 1, 6 de diciembre de 2014, pp. 117-127, ISSN 1099-209X, 1874-9380, DOI 10.1007/s12230-014-9422-8.
2. Dambreville, A.; Lauri, P.-É.; Normand, F. y Guédon, Y. “Analysing growth and development of plants jointly using developmental growth stages’’, *Annals of Botany*, vol. 115, no. 1, 1 de enero de 2015, pp. 93-105, ISSN 0305-7364, 1095-8290, DOI 10.1093/aob/mcu227, [PMID: 25452250].
3. Santos Castellanos, M.; Segura Abril, M.; López, Ñ. y Eduardo, C. ‘‘Análisis de Crecimiento y Relación Fuente-Demanda de Cuatro Variedades de Papa (*Solanum tuberosum* L.) en el Municipio de Zipaquirá (Cundinamarca, Colombia)’’, *Revista Facultad Nacional de Agronomía, Medellín*, vol. 63, no. 1, junio de 2010, pp. 5253-5266, ISSN 0304-2847.
4. Molahlehi, L.; Steyn, J.M. y Haverkort, A.J. “Potato Crop Response to Genotype and Environment in a Subtropical Highland Agro-ecology’’, *Potato Research*, vol. 56, no. 3, 6 de agosto de 2013, pp. 237-258, ISSN 0014-3065, 1871-4528, DOI 10.1007/s11540-013-9241-1.
5. Tyagi, V.K.; Thenua, O.V.S.; Kumar, D. y Singh, N. “Dry matter production, seed yield and economics of French bean under different cropping system and irrigation regimes’’, *Indian Journal of Plant Physiology*, vol. 18, no. 1, 23 de abril de 2013, pp. 73-77, ISSN 0019-5502, 0974-0252, DOI 10.1007/s40502-013-0012-4.
6. Hernández, N. y Soto, F. ‘‘Influencia de tres fechas de siembra sobre el crecimiento y la relación fuente-demanda del cultivo del maíz (*Zea mays* L.)’’, *Cultivos Tropicales*, vol. 33, no. 1, marzo de 2012, pp. 28-34, ISSN 0258-5936.
7. Sánchez-Bernal, E.I.; Escobar, M.O.; Hernández, V.G.; Escobar, M.A.C. y Kohashi-Shibata, J. ‘‘Crecimiento de plantas de papa (*Solanum tuberosum* L.) cv. Alpha, inducido por diversas soluciones salinas’’, *Interciencia: Revista de ciencia y tecnología de América*, vol. 33, no. 9, 2008, pp. 643-650, ISSN 0378-1844.
8. Hernández, A.; Pérez, J.; Bosch, D. y Castro, N. *Clasificación de los suelos de Cuba 2015*, edit. Ediciones INCA, Mayabeque, Cuba, 2015, p. 93, ISBN 978-959-7023-77-7.
9. Deroncelé, R.; Salomón, J.; Manso, F.; Linares, J.; Santo, R.; Roque, R.; González, P.; Navarro, H. y Tabera, O. *Guía técnica para la producción de papa en Cuba*, edit. Liliana, La Habana, Cuba, 2000, p. 42, ISBN 959-7111-05-05.
10. Statistical Graphics Crop *STATGRAPHICS® Plus* [en línea], versión 5.1, [Windows], 2000, (ser. Profesional), Disponible en: <http://www.statgraphics.com/statgraphics/statgraphics.nsf/pd/pdpricing>.
11. Rykaczewska, K. ‘‘The Effect of High Temperature Occurring in Subsequent Stages of Plant Development on Potato Yield and Tuber Physiological Defects’’, *American Journal of Potato Research*, vol. 92, no. 3, 11 de febrero de 2015, pp. 339-349, ISSN 1099-209X, 1874-9380, DOI 10.1007/s12230-015-9436-x.

12. Monneveux, P.; Ramírez, D.A.; Khan, M.A.; Raymundo, R.M.; Loayza, H. y Quiroz, R. "Drought and Heat Tolerance Evaluation in Potato (*Solanum tuberosum* L.)", *Potato Research*, vol. 57, no. 3-4, 23 de diciembre de 2014, pp. 225-247, ISSN 0014-3065, 1871-4528, DOI 10.1007/s11540-014-9263-3.
13. Aspinall, R. *Manual of Methods for Soil and Land Evaluation*. [en línea], (ed. Costantini, E.A.C.), edit. Enfield, Science, 2009, p. 549, ISBN 978-1-57808-571-2, [Consultado: 8 de septiembre de 2015], Disponible en: <http://journals.cambridge.org/article_S0014479710000499>.
14. Kharshiing, E. y Sinha, S.P. "Plant Productivity: Can Photoreceptors Light the Way?", *Journal of Plant Growth Regulation*, vol. 34, no. 1, 9 de octubre de 2014, pp. 206-214, ISSN 0721-7595, 1435-8107, DOI 10.1007/s00344-014-9454-9.
15. Praharaj, C.S.; Govindakrishnan, P.M. y Lal, S.S. "Dry matter distribution in potato genotypes as affected by physiological degree days", *Potato Journal*, vol. 37, no. 3-4, 2010, ISSN 0973-5909, [Consultado: 8 de septiembre de 2015], Disponible en: <http://epubs.icar.org.in/ejournal/index.php/PotatoJ/article/view/32625>.
16. Aien, A.; Khetarpal, S. y Pal, M. "Photosynthetic characteristics of potato cultivars grown under high temperature", *American–Eurasian Journal of Agricultural and Environmental Sciences*, vol. 11, no. 5, 2011, pp. 633–639, ISSN 1818-6769.
17. Haverkort, A.J.; Franke, A.C.; Engelbrecht, F.A. y Steyn, J.M. "Climate Change and Potato Production in Contrasting South African Agro-ecosystems 1. Effects on Land and Water Use Efficiencies", *Potato Research*, vol. 56, no. 1, 7 de marzo de 2013, pp. 31-50, ISSN 0014-3065, 1871-4528, DOI 10.1007/s11540-013-9230-4.
18. Levy, D.; Coleman, W.K. y Veilleux, R.E. "Adaptation of Potato to Water Shortage: Irrigation Management and Enhancement of Tolerance to Drought and Salinity", *American Journal of Potato Research*, vol. 90, no. 2, 11 de enero de 2013, pp. 186-206, ISSN 1099-209X, 1874-9380, DOI 10.1007/s12230-012-9291-y.
19. Attia, Z.; Domec, J.-C.; Oren, R.; Way, D.A. y Moshelion, M. "Growth and physiological responses of isohydric and anisohydric poplars to drought", *Journal of Experimental Botany*, 7 de mayo de 2015, p. erv195, ISSN 0022-0957, 1460-2431, DOI 10.1093/jxb/erv195, [PMID: 25954045].
20. Asensi-Fabado, A.; García-Breijo, F.J. y Reig-Armiñana, J. "Ozone-induced reductions in below-ground biomass: an anatomical approach in potato", *Plant, Cell & Environment*, vol. 33, no. 7, 1 de julio de 2010, pp. 1070-1083, ISSN 1365-3040, DOI 10.1111/j.1365-3040.2010.02128.x.
21. Caicedo, D.R.; Tellez, M.S.R.; Molano, L.E.R. y López, C.E.Ñ. "Efecto de diferentes niveles y épocas de defoliación sobre el rendimiento de la papa (*Solanum tuberosum* cv. Parda Pastusa)", *Revista Facultad Nacional de Agronomía, Medellín*, vol. 63, no. 2, 2010, pp. 5521–5531, ISSN 0304-2847.
22. Jerez Mompies, E. y Martín Martín, R. "Comportamiento del crecimiento y el rendimiento de la variedad de papa (*Solanum tuberosum* L.) Spunta", *Cultivos Tropicales*, vol. 33, no. 4, diciembre de 2012, pp. 53-58, ISSN 0258-5936.
23. Fajardo, D.; Haynes, K.G. y Jansky, S. "Starch Characteristics of Modern and Heirloom Potato Cultivars", *American Journal of Potato Research*, vol. 90, no. 5, 14 de mayo de 2013, pp. 460-469, ISSN 1099-209X, 1874-9380, DOI 10.1007/s12230-013-9320-5.
24. Irigoyen, I.; Domeño, I. y Muro, J. "Effect of Defoliation by Simulated Hail Damage on Yield of Potato Cultivars with Different Maturity Performed in Spain", *American Journal of Potato Research*, vol. 88, no. 1, 2 de septiembre de 2010, pp. 82-90, ISSN 1099-209X, 1874-9380, DOI 10.1007/s12230-010-9166-z.
25. Hancock, R.D.; Morris, W.L.; Ducreux, L.J.M.; Morris, J.A.; Usman, M.; Verrall, S.R.; Fuller, J.; Simpson, C.G.; Zhang, R.; Hedley, P.E. y Taylor, M.A. "Physiological, biochemical and molecular responses of the potato (*Solanum tuberosum* L.) plant to moderately elevated temperature", *Plant, Cell & Environment*, vol. 37, no. 2, 1 de febrero de 2014, pp. 439-450, ISSN 1365-3040, DOI 10.1111/pce.12168.
26. Condori, B.; Mamani, P.; Botello, R.; Patiño, F.; Devaux, A. y Ledent, J.F. "Agrophysiological characterisation and parametrisation of Andean tubers: Potato (*Solanum* sp.), oca (*Oxalis tuberosa*), isaño (*Tropaeolum tuberosum*) and papalisa (*Ullucus tuberosus*)", *European Journal of Agronomy*, vol. 28, no. 4, mayo de 2008, pp. 526-540, ISSN 1161-0301, DOI 10.1016/j.eja.2007.12.002.
27. Leiva Mora, M.; Portela Díaz, Y.; Torres García, S.; Veitía, N.; Jiménez Terry, F.; Agramonte, D.; León, M.; Alvarado Capó, Y.; Acosta Suárez, M. y Cruz Martín, M. "Índices fisiológicos asociados al crecimiento de variedades de papa obtenidas por métodos biotecnológicos", *Biotecnología vegetal*, vol. 11, no. 2, 2011, pp. 119–120, ISSN 1609-1841.

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