Cultivos Tropicales, 2016, vol. 37, no. 2, pp. 88-95 April-June

ISSN impreso: 0258-5936
ISSN digital: 1819-4087

DOI: 10.13140/RG.2.1.1452.1842
http://dx.doi.org/10.13140/RG.2.1.1452.1842

Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas
http://ediciones.inca.edu.cu

EFFECTS OF DIFFERENT PLANT SPACINGS AND SEED TUBER SIZES ON SOME MORPHO-PRODUCTIVE CHARACTERISTICS OF POTATO IN HUAMBO, ANGOLA

Efectos de diferentes distancias de plantación y calibres de tubérculos-semilla sobre algunas características morfo-productivas de la papa en Huambo, Angola

Fernando M. de Almeida[1]✉, Jorge Arzuaga Sánchez[2], Walfredo Torres de la Noval[2] and Juan A. Cabrera Rodríguez[2]

ABSTRACT. The present investigation was carried out in Huambo province, Angola, from October 2011 up to January 2014, with the objective of evaluating the effect of four plant spacings and three seed tuber sizes on some morpho-productive characteristics of potato cv. Romano. Row spacing was of 90 cm whereas plant spacings of 15, 20, 25 and 30 cm were studied along with seed tuber sizes of 28-35 mm, 35-45 mm and 45-55 mm, for a total of 13 treatments, including a control and a reference control. The evaluated variables were plant height, stem diameter and stem number per square meter, leaf area and total yield. Results showed that, under the soil and climatic conditions of Huambo, stem diameter and leaf area, 75 days after planting (DAP), were benefited by extending plant spacing and using greater seed tuber sizes. However, plant height and stem number increased when reducing plant spacing. On the other hand, average yields of 16,4 t ha^{-1} were achieved by using seed tuber sizes of 35-45 mm at a plant spacing of 90 x 30 cm.

Key words: deficit, plant density, potato, morphology, seeds

RESUMEN. Durante el periodo comprendido desde octubre hasta enero de los años 2011-2014, se realizó la presente investigación en la provincia de Huambo, Angola, con el objetivo de evaluar el efecto de cuatro distancias de plantación y tres calibres de tubérculos-semilla, sobre algunas características morfoproductivas de la papa, variedad Romano. La distancia entre surcos fue de 90 cm y se estudiaron las distancias entre plantas de 15, 20, 25 y 30 cm, combinadas con calibres de tubérculos-semilla de 28-35 mm, 35-45 mm y 45-55 mm, para un total de 13 tratamientos estudiados, que incluyeron un testigo y un testigo de referencia. Las variables evaluadas fueron la altura, el diámetro, el número de tallos por metro cuadrado, el área foliar y el rendimiento total. Los resultados demostraron que bajo las condiciones edafoclimáticas de Huambo, Angola; el diámetro del tallo y el área foliar a los 75 días después de la plantación (ddp), se beneficiaron al aumentar la distancia de plantación y el uso de calibres con mayor tamaño. Por el contrario, la altura y el número de tallos aumentaron con la disminución del espacio. Por otro lado, con el empleo de calibres entre 35-45 mm, a una distancia de plantación de 90 x 30 cm, se obtuvieron rendimientos promedio de 16,4 t ha^{-1}.

Palabras clave: déficit, densidad, papa, morfología, semillas

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the main crop among those producing roots and tubers, and the third most important food crop in the world after rice and wheat. It is harvested in more than 125 countries, besides being consumed by over a billion people (1).

[1]Universidad "José Eduardo dos Santos", en Chianga, Huambo, Angola

[2] Instituto Nacional de Ciencias Agrícolas (INCA), gaveta postal 1, San José de las Lajas, Mayabeque, Cuba, CP 32 700.

✉ fernandomanueldealmeida@yahoo.com

It is widely accepted and many families depend on it as a primary and secondary source of food and nutrition. It is very nutritious, as it is rich in protein, calcium, potassium and vitamin C, in addition to a good amino acid balance. It is very productive and produces more food per capita in time and space than wheat, rice and maize (2).

China, India and the Russian Federation are among the highest potato-producing countries in the world; however, top yields are between 41 and 45 t ha^{-1}, mainly concentrated in the Netherlands, Germany and the United States (3).

Particularly in Africa, over the latest decades, marketable potato production has increased from 2 million tons in 1960 up to near 16.7 million tons in 2007, with an average yield of 10,8 t ha^{-1}, despite being developed in a wide range of soil and climatic conditions. Egypt, Malawi, South Africa and Algeria provide 59 % of the entire potato produced in Africa.

Within the African continent, Angola devotes about 120 000 ha to potato crop, reaching an average production of 615 000 tons; particularly in Huambo, both potato production and acreage are significant, obtaining an average annual yield between 5 and 7 t ha^{-1} that is extended to the whole country, either for the farmer or private sector. They are still very low if compared with those obtained in South Africa, which are from 24 to 34 t ha^{-1} (3).

Several factors could influence on low yields of potato production in Angola, specifically in Huambo. Crop management is one of them, which is fully applied by small producers' hands, except soil preparation. This suggests that agro-technical and human factors may cause low yields. Some research studies carried out in Turkey and Brazil provide results on increased potato yields when agro-technical criteria are regarded (4, 5).

During potato production process in Angola, particularly in Huambo, planting frames are very diverse and have not yet reached a consensus, as each grower uses the spacing according to his own criteria. On the other hand, seed tubers should be classified into a greater size number, in order to standardize stem density and plant height, as well as to enable management and other cultural practices aimed to reach the highest yield (6).

As it is mentioned above, this research was conducted with the objective of determining the effect of four plant spacings and three seed tuber sizes on some morpho-productive characteristics of potato (*Solanum tuberosum* L.) cv. Romano, in Huambo province, Angola.

MATERIALS AND METHODS

The experiment was performed at Chianga Research Center, pertaining to the Agronomic Research Institute (IIA), located in Huambo province, Angola, over the period from October 2011 to January 2014, on a Distric, typical, Lixiviated Red Ferralitic soil (7), indexed as Distric and Rhodic Acrisol, according to the World Reference Base (8). It has some limiting factors as a result of its natural characteristics, such as acidity, low organic matter content, high content of available phosphorus and medium to low content of available potassium.

During the experiment, climate behavior in Huambo was adequate for crop development. Average annual temperature ranged between 19 and 20 °C, with monthly top values equivalent to 180 mm rainfall and a relative humidity ranging from 60 to 80 %.

Potato cv. Romano of local production was used on a randomized block design with factorial arrangement and the following factors:

Factor A: seed tuber sizes of 28-35, 35-45 and 45-55 mm

Factor B: plant spacings of 15, 20, 25 and 30 cm; row spacing of 90 cm

The control treatment was constituted by the plant spacing and seed tuber size often used by growers in Huambo (plant spacing of 20 cm with seed tuber size of 28-35 mm). A reference control was also used with a similar combination of factors to the control treatment, but a different application of mineral fertilizer, since only a dose of 600 kg ha^{-1} of 12-24-12 formula was applied by hand, as traditionally used by growers in the region. However, in the other treatments, apart from this application, 220 kg ha^{-1} KCl was added at planting time and 132 kg ha^{-1} N as urea (290 kg ha^{-1}) 30-35 days after planting, so that 205, 144 and 204 kg ha^{-1} N, P_2O_5 and K_2O were respectively provided as a whole.

As a result of combining factors, its levels and control treatments, a group of 13 treatments arranged in four replicates were studied (Table I).

Table I. Description of experimental treatments

Treatments	Seed tuber size (mm)	Plant spacing (cm)	Row spacing (cm)
1	28-35	15	
2 (control)	28-35	20	
3	28-35	25	
4	28-35	30	
5	35-45	15	
6	35-45	20	
7	35-45	25	
8	35-45	30	90
9	45-55	15	
10	45-55	20	
11	45-55	25	
12	45-55	30	
13 (reference control)	28-35	20	

Cultural practices, except soil preparation, such as planting, weeding, pest control and harvesting were developed by hand, according to vegetable production rules from the Ministry of Agriculture of Angola[A]. Crop water demands were satisfied depending on rainfall occurrence during the experimental period mentioned in the above paragraph.

The morpho-productive variables evaluated were:

Stem height (cm): 20 plants per plot were evaluated 60-65 days after planting (dap) by choosing the highest stem and measuring it from its base to the apical bud with a ruler.

Main stem diameter (mm): 20 plants per plot were evaluated 60-65 days after planting by taking the highest stem and measuring it at 10 cm soil surface digitally measured with ± 0,1 mm error.

Stem number m^{-2}: 20 plants per plot and stem number per plant were recorded 60-65 dap by visual counting, determining the area occupied by each plant, according to plant spacing and calculating stem number per m^2.

Leaf area (dm^2): it was calculated when sampling 20 plants randomly selected from the linear measurements of its leaves (length, width and their product) 30, 60 and 75 dap, estimating leaf surface from the previously obtained regression equation (y= 0,89x+2,75), where x represents the product of length by width and values within the function, the linear equation parameters, its slope and the intercept with y axis. It was nondestructively attained from the linear measurements of its leaves and considering the background studies (9), specially focusing on the variety used in the present study.

Total estimated yield (t ha^{-1}): it was obtained from dividing the total tuber mass by 1000 kg (one ton) and the results were divided by the harvested area (in hectares).

A statistical analysis was performed on the information of evaluations, taking into account the design used, so that data were processed through a two-way classification variance analysis (ANOVA) and the multiple comparison of means was made by Duncan's Multiple Range test in cases of significant differences, using STATGRAPHICS PLUS statistical package version 5.1 (10).

RESULTS AND DISCUSSION

The factorial variance analysis showed statistically significant differences between the studied factors for all morphological variables evaluated: height, diameter and stem number per square meter; therefore, there were interactions between them. Table II presents the results of statistical analysis, where statistically significant differences were recorded between treatments in the three variables studied.

Stem height

The greatest stem height values were registered in plants established with seed tuber sizes of 28-35 and 35-45 mm, at a plant spacing of 15 cm, without significant differences between them, followed by the treatment where the crop was planted with seed tuber sizes of 45-55 mm, at the same plant spacing than before. Conversely, the lowest plant height was evaluated in the control treatment, without significant differences with the treatment, where plants developed from crop establishment with seed tuber sizes of 45-55 mm at a plant spacing of 30 cm.

According to the results described above, it was observed that for the three seed tuber sizes, when plant spacing decreases, stem height increases; however, the highest average values were evaluated with the lowest seed tuber sizes.

[A] Ministério de la Agricultura de Angola. *Alguns procedimentos técnicos e recomendações para pequenos e medios productores de culturas das Hotaliças nas zonas rurais de Angola*. 1980, Documento Base, 20 p.

Table II. Influence of different seed tuber sizes and plant spacings on some morphological characteristics of potato crop

Treatments	Stem height (cm)	Stem diameter (mm)	Stem number /m²
28-35 mm x 15 cm	58,22 a	8,65 g	17,29 de
28-35 mm x 20 cm (control)	56,38 c	8,987 f	12,82 gh
28-35 mm x 25 cm	51,03 e	9,30 e	12,73 h
28-35 mm x 30 cm	48,36 h	10,06 c	10,67 hi
35-45 mm x 15 cm	58,74 a	9,41 e	26,20 b
35-45 mm x 20 cm	54,96 d	9,74 d	19,59 cd
35-45 mm x 25 cm	50,05 f	10,05 c	15,77 ef
35-45 mm x 30 cm	47,78 hi	11,03 b	13,56 fg
45-55 mm x 15 cm	57,56 b	9,39 e	38,58 a
45-55 mm x 20 cm	54,84 d	9,86 cd	27,42 b
45-55 mm x 25 cm	49,28 g	9,85 cd	21,81 c
45-55 mm x 30 cm	47,50 i	11,46 a	18,67 de
28-35 mm x 20 cm (reference control)	46,11 i	8,71 fg	9,20 i
SE±	0,3775**	0,0790**	0,6843**

Means with different letters in the same column differ significantly for p≤0,05 according to Duncan's Multiple Range test

These results may be related to the effect of self-shading of plants from higher plantation densities and the consequent increase in auxin concentration, as light is reduced on these tissues, causing cell elongation, since indoleacetic acid increases and acts synergistically with gibberellins under shade conditions (11).

Some investigations conducted on this subject determined that when population density was higher, plant height increased from 30 to 75 dap; moreover, plants established at lower density grew 31 % less than those established at higher plant density (12).

Stem diameter

Unlike what is described for stem height, the largest stem diameter was recorded in the treatment planted with the highest seed tuber size and plant spacing, followed by the treatment with tubers planted at the same plant spacing but with size of 35-45 mm, showing statistically significant differences between them. On the other hand, the lowest values of this variable were recorded in the control treatment, without statistically significant differences with the treatments where potato was planted with sizes between 28-35 mm and row spacings of 15 and 20 cm.

Considering the results of this variable, we can infer the effect of those factors studied on stem diameter. In this context, potato stem diameter like other crops is a vegetative growth indicator, which means that plants achieved greater vegetative vigor with a larger seed tuber size and a lower plant density. A different height dynamics was also evaluated for the three sizes used, as stem diameter decreased when plant spacing was reduced, and the largest stem diameters were recorded in the greatest seed tuber sizes.

Stem number per square meter

The highest amount of stems with an average of 38,58 m^2 were observed in the treatment where plants were grown from seed tuber sizes of 45-55 mm at a plant spacing of 15 cm, followed by those established from the same size at a plant spacing of 20 cm, with statistically significant differences between them.

On the other hand, the fewest stems were produced in plants established in the control treatment, without statistically significant differences with those developed from tuber size of 30 cm at a plant spacing of 30 cm.

In general, within the same seed tuber size, as plant spacing decreases, the number of stems per unit area increases; this variable was favored by larger seed tuber sizes.

The best way to determine the optimal number of stems for a specific area is to experiment with different plant spacings and tuber sizes by using commonly grown varieties in the area. In this context, the importance of recognizing the influence of seed tuber sizes on the number of stems per square meter was proved; a morpho-productive indicator that defines final crop results, considering the direct relationship between stem number and tuber production that contributes to final yields[B].

[B] Montes de Oca, F. M. *Guía para la producción, comercialización y uso de semilla de papa de calidad*. PNTR-INIAP-Proyecto Fortipapa, 2005, p. 40.

Some experiments developed on this subject showed that the number of tubers per plant increased with the number of stems, whereas the average size of commercial tubers was significantly reduced (13).

Leaf area behavior

Factorial variance analysis showed no statistically significant differences between factors for this variable 30 dap (Table III). Therefore, it seems that the seed tuber sizes and plant spacings used did not have any influence on leaf area during this period. Furthermore, there was no significant factor interaction on this indicator for a confidence level of 95 %.

Results may be related to the poor vegetative development of potato plants 30 days after planting, when even stem height cannot exceed 30 cm; however, factorial statistical analysis over the periods evaluated 60 and 75 dap showed statistically significant differences between factors for this variable (Table IV).

Table III. Influence of different seed tuber sizes and plant spacings on potato leaf area 30 dap

Factors	Leaf area (dm^2)
Seed tuber size	
28-35 mm	6,41
35-45 mm	6,97
45-55 mm	6,75
SE±	0,3457 NS
Plant spacing	
15	6,93
20	6,77
25	6,71
30	6,43
SE±	0,4061 NS

Means with different letters in the same column differ significantly for p≤0,05 according to Duncan's Multiple Range test

There were no significant differences between treatments 60 dap; therefore, leaf area was similar despite they were planted at different planting densities and seed tuber sizes; however, there were statistically significant differences between treatments 75 dap.

This variable showed the highest values 60 dap with a general mean of 30,11 dm^2, which decreased to 19,49 dm^2 75 dap. Within both evaluative periods, as plant spacing increased, leaf area became larger in every seed tuber size studied. This may be related to a decreased interspecific competition caused by the effect of plant spacing, so that plants showed a wider leaf area in correspondence with greater plant spacings.

Table IV. Influence of different seed tuber sizes and plant spacings on potato leaf area (dm^2) 60 and 75 dap

Treatments	60 dap	75 dap
28-35 mm x 15 cm	33,02	18,05 b
28-35 mm x 20 cm (control)	27,06	19,19 b
28-35 mm x 25 cm	26,86	19,40 b
28-35 mm x 30 cm	27,48	20,39 ab
35-45 mm x 15 cm	31,39	19,11 b
35-45 mm x 20 cm	31,49	19,13 b
35-45 mm x 25 cm	32,13	20,73 ab
35-45 mm x 30 cm	33,66	22,10 a
45-55 mm x 15 cm	28,40	18,08 b
45-55 mm x 20 cm	29,53	19,20 ab
45-55 mm x 25 cm	29,95	19,67 ab
45-55 mm x 30 cm	30,92	20,33 ab
28-35 mm x 20 cm (reference control)	26,05	18,01 b
SE±	0,9633 ns	0,2617 **

Means with different letters in the same column differ significantly for p≤0,05 according to Duncan's Multiple Range test

Likewise, a wider leaf area was reached in plants established from seed tuber sizes of 35-45 mm at a plant spacing of 30 cm, meanwhile the narrowest leaf area was observed with the smallest seed tuber sizes, including the control treatment with the lowest value of this variable. This may be related to the relationship between seed tuber sizes used and the number of stems, because small sizes usually lead to fewer outbreaks, thereby to fewer stems, which at the same time lead to a narrower leaf area and all this has a significant impact on yield.

Some experiments have decreased leaf area from 28,79 dm^2 when potato was planted at a spacing of 40 cm up to 17,67 dm^2 at a spacing of 10 cm and have influenced on marketable yield, as it decreased from 21,19 to 18,27 t ha^{-1} (14).

In general, an increasing rate of this indicator was achieved in all treatments from 30 to 60 dap and after that these values decreased up to 75 dap, because this is a semi-early cycle variety with an average life cycle of 90 days. Thus, its vegetative growth decreased from 70-75 dap, thereby new leaves grew, others became older and leaf area was reduced. Some research studies conducted on this subject with *Tollocan* variety recorded leaf area values of 31,52 and 25,20 cm^2 at saline concentrations in the control treatment 50 and 80 dap respectively (15).

An efficient interception of radiation on crop surface requires an adequate leaf area evenly distributed to achieve a complete soil cover. This is possible with the proper management of plant density and its distribution on the ground surface.

Due to the importance of leaf area analysis on photo-assimilate production for crop growth and development, the results of this research study shows the significance of considering plant spacings and seed tuber sizes on potato development.

Total estimated yield

Regarding the three seed tuber sizes studied, the highest yields were achieved in treatments planted at a plant spacing of 30 cm whereas the highest values were recorded in the treatment established with seed tuber sizes of 35-45 mm, reaching an average yield of 16,34 t ha^{-1} (Figure).

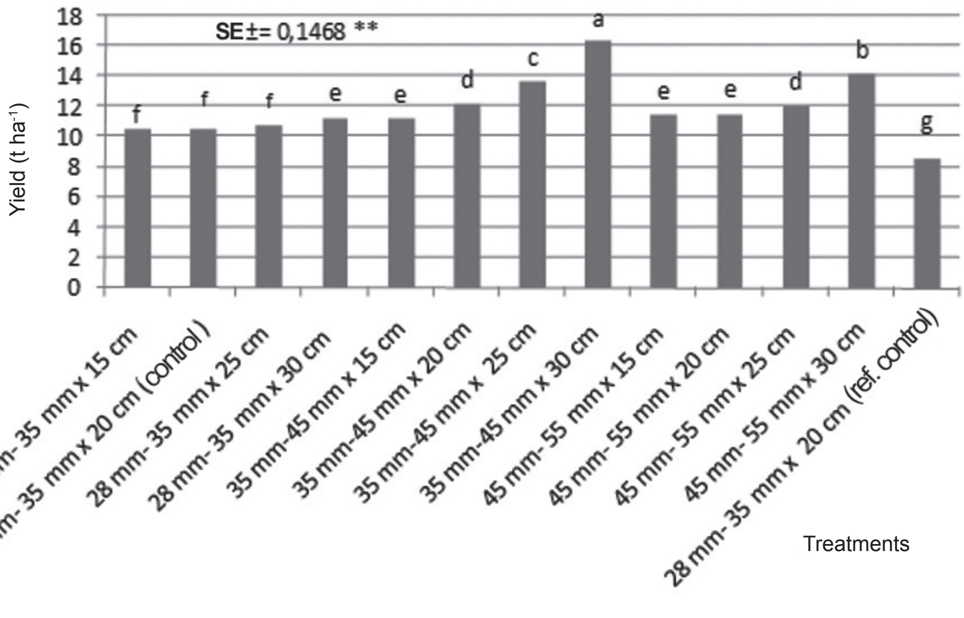
On the other hand, the lowest yields were obtained in the reference control treatment, with an average value of 8,53 t ha^{-1}. Such productive results are in agreement with the values recorded by the growers' surveys related to the diagnosis performed to know the problems existing in Huambo, since its yields are between 3 and 10 t ha^{-1}.

From the productive point of view, results show the positive influence of tubers on total yield, if there is an adequate management to establish potato crop, taking into account seed tuber size and plant spacing.

In general, it was observed that as long as plant spacing (plant density reduction) and seed tuber size increased, yields were higher. Similar results have shown higher yields at a spacing of 90 x 30 cm, which also increased with plant density reduction and bigger seed tuber size (16).

These results do not match with those obtained in previous studies conducted with the aim of producing seed tubers under different soil and climate conditions from those of this study (17), with yields of 33,42 t ha^{-1} at a plant spacing of 15 cm and 24,21 t ha^{-1} at 30 cm. Other researchers have stated that tuber yields per hectare decreased with wider plant spacings, due to a higher number of tubers harvested in these areas, the highest yield being of 36,44 t ha^{-1} (4, 18, 19). On the other hand, potato yields of 34,43 t ha^{-1} have been obtained at a plant spacing of 10 cm and 26,09 t ha^{-1} at 40 cm (13).

Potato yield depends on the average growth rate and its growth length. In this context, the most important ratio is extended from the end of leaf growth until the ends of potato growth, when almost all available assimilates are used for tuber growth.



Influence of three seed tuber sizes and different plant spacings on the total potato yield estimated in Huambo province, Angola

There are many factors influencing potato yield, such as the soil and climate that play an essential role on the morphological and physiological characteristics determining yield. Results with four potato varieties in the State of Trujillo, Venezuela, allowed inferring that the last yield expression of all materials tested was mainly due to their adaptation to the agro-ecological conditions under which this study was conducted, rather than to other variables evaluated as the number of stems (20).

Consequently, the climatic conditions of Huambo enhanced crop agro-climatic requirements during the investigation; therefore, morpho-productive characteristics were also improved (21).

Experimental soil conditions, which are representative of Huambo, also had significant influence on treatment behavior, as it was observed in all variables. The poor results of morpho-productive variables evaluated in the reference control treatment resulted from soil productive limitations.

Low soil content of organic matter and available potassium could be the main causes of poor crop growth and development, in addition to low potato yields in the reference control treatment, compared with the other treatments, because it did not receive additional doses of potassium, the highest daily required element and the largest soil extraction per each ton of potatoes produced (7,6 kg t^{-1}).

The role of potassium in potato plants is essential for water saving, due to its action in cell turgidity, photosynthesis, respiration, synthesis, transport of sugars and starch towards tubers, fat and protein metabolism; it is the main nutrient that regulates enzymatic activity and activation, which supports its great demand by the crop. This element promotes leaf area index and its length as well as increases harvest rate, tuber size and weight[C].

CONCLUSIONS

- Potato stem diameter and leaf area 75 dap are favored by wider plant spacings and larger seed tuber sizes; however, stem height and number increase with plant space reduction and smaller seed tuber sizes.
- The use of seed tuber sizes between 35 and 45 mm at a plant spacing of 90 x 30 cm enabled to achieve average yields of 16,4 t ha^{-1} under the soil and climatic conditions of Huambo, Angola.

[C] Esteves, A. *El cultivo de la papa en Cuba*. Inst. INCA, 2007, 534 p.

BIBLIOGRAPHY

1. Lutaladio, N.; Ortiz, O.; Haverkort, A.; Caldiz, D.; Lutaladio, N.; Ortiz, O.; Haverkort, A. y Caldiz, D. *Sustainable potato production: guidelines for developing countries.* [en línea]. edit. Food and Agriculture Organization of the United Nations (FAO), 2009, 91 p., ISBN 978-92-5-106409-2, [Consultado: 11 de enero de 2016], Disponible en: <http://www.cabdirect.org/abstracts/20103083016.html>.
2. Kaguongo, W.; Nyangweso, A.; Mutunga, J.; John Nderitu, J.; Lunga'ho, C.; Nganga, N.; Kipkoech, D.; Kabira, J.; Gathumbi, M.; Njane, P.; Irungu, J.; Onyango, A.; Borus, D. y Schulte-Geldermann, E. *A policymakers' guide to crop diversification: The case of the potato in Kenya* [en línea]. edit. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, 2013, 70 p., ISBN 978-92-5-107728-3, [Consultado: 11 de enero de 2016], Disponible en: <https://cgspace.cgiar.org/handle/10568/57009>.
3. FAO. *Statistical yearbook 2013. Word food agriculture*. edit. Food and Agriculture Organization of the United Nations (FAO), Roma, 2013, 289 p., ISBN 978-92-5-107396-4.
4. Güllüoglu, L. y Arioglu, H. "Effects of seed size and in-row spacing on growth and yield of early potato in a mediterranean-type environment in Turkey". *African journal of agricultural research*, vol. 4, no. 5, 1 de mayo de 2009, pp. 535-541, ISSN 1991-637X.
5. Queiroz, L. R. de M.; Kawakami, J.; Muller, M. M. L.; Umburanas, R. C. y Eschemback, V. "Tamanho de tubérculo-semente e espaçamento na produtividade de batata em condições de campo". *Comunicata Scientiae*, vol. 4, no. 3, 1 de octubre de 2013, pp. 308-315, ISSN 2177-5133.
6. Bisognin, D. A.; Müller, D. R.; Streck, N. A.; Andriolo, J. L. y Sausen, D. "Desenvolvimento e rendimento de clones de batata na primavera e no outono". *Pesquisa Agropecuária Brasileira*, vol. 43, no. 6, 2008, pp. 699–705, ISSN 1678-3921.
7. Hernández, A.; Pérez, J.; Bosch, D. y Castro, N. *Clasificación de los suelos de Cuba 2015*. edit. Ediciones INCA, Mayabeque, Cuba, 2015, 93 p., ISBN 978-959-7023-77-7.
8. IUSS Working Group WRB. *World Reference Base for soil resources 2014: international soil classification system for naming soils and creating legends for soil maps*. (ser. World Soil Reports, no. ser. 106), edit. Food and Agriculture Organization of the United Nations, Rome, 2014, ISBN 978-92-5-108370-3.
9. Jerez Mompie, E.; Martín, M. R. y Díaz, H. Y. "Estimación de la superficie foliar en dos variedades de papa (*Solanum tuberosum* L.) por métodos no destructivos". *Cultivos Tropicales*, vol. 35, no. 1, marzo de 2014, pp. 57-61, ISSN 0258-5936.
10. Statistical Graphics Crop. *STATGRAPHICS® Plus* [en línea]. (ser. Profesional), versión 5.1, [Windows], 2000, Disponible en: <http://www.statgraphics.com/statgraphics/statgraphics.nsf/pd/pdpricing>.

11. Vázquez, B. E. y Torres, S. *Fisiología Vegetal*. vol. 2, edit. Félix Varela, La Habana, Cuba, 2006, 349 p., ISBN 959-258-21-4.
12. Flores, L. R.; Sánchez, del C. F.; Rodríguez, P. J. E.; Colinas, L. M. T.; Mora, A. R. y Lozoya, S. H. "Densidad de población en cultivo hidropónico para la producción de tubérculo-semilla de papa (*Solanum tuberosum* L.)". *Revista Chapingo. Serie horticultura*, vol. 15, no. 3, diciembre de 2009, pp. 251-258, ISSN 1027-152X.
13. García, S. T.; Morera, J. L. C.; Aro, M. H.; Díaz, Y. P. y Figueroa, E. G. "El número de tallos por plantón afecta el crecimiento y rendimiento de la papa variedad Cal White". *Centro Agrícola*, vol. 39, no. 1, 2012, pp. 11–16, ISSN 0253-5785, 2072-2001.
14. Getachew, T.; Belew, D. y Tulu, S. "Yield and Growth Parameters of Potato (*Solanum tuberosum* L.) as Influenced by Intra Row Spacing and Time of Earthing Up: In Boneya Degem District, Central Highlands of Ethiopia". *International Journal of Agricultural Research*, vol. 7, no. 5, 2012, pp. 255–265, ISSN 1816-4897, DOI 10.3923/ijar.2012.255.265.
15. Sanchez, B. E. I.; Camacho, E. M. A.; Rodriguez, L. A. y Ortega, E. H. M. "Physiological Behavior of Potato cv. *Tollocan* at Diverse Types of Salinity". *Journal of Plant Studies*, vol. 2, no. 1, 8 de enero de 2013, pp. 67-89, ISSN 1927-047X, 1927-0461, DOI 10.5539/jps.v2n1p120.
16. Masarirambi, M. T.; Mandisodza, F. C.; Mashingaidze, A. B. y Bhebhe, E. "Influence of plant population and seed tuber size on growth and yield components of potato (*Solanum tuberosum*)". *International Journal of Agriculture & Biology*, vol. 14, no. 4, 2012, pp. 545-549, ISSN 1560–8530, 1814–9596.
17. Hernandez, H. "Influencia de la distancia de plantación en la obtención de papa para semilla y dinámica del crecimiento de los tubérculos en la variedad Desiree Nacional clase «E»". *Cultivos Tropicales*, vol. 4, no. 2, 1982, pp. 335–344, ISSN 0258-5936.
18. Zamil, M. F.; Rahman, M. M.; Robanni, M. G. y Khatun, T. "Combined effect of nitogen and plant spacing on growth and yield of potato with economic performance". *Bangladesh Research Publications Journal*, vol. 3, no. 3, 2010, pp. 1062-1070, ISSN 1998-2003.
19. Zabihi, M. R.; Jamaati, S. S.; Khayatnezhad, M. y Gholamin, R. "Correlation of tuber yield whit yield components of potato affected by nitrogen application rate in different plant density". *Advances in Environmental Biology*, vol. 5, no. 1, 1 de enero de 2011, pp. 131-136, ISSN 19950756.
20. Quintero, I.; Montero, F.; Zambrano, J.; Meza, M.; Maffei, M.; Valera, A. y Alvarez, R. "Evaluación de once clones promisorios de papa (*Solanum tuberosum* L.) en el estado Trujillo. I Crecimiento, desarrollo y rendimiento". *Revista de la Facultad de Agronomía*, vol. 26, no. 3, 2009, pp. 362-381, ISSN 0378-7818.
21. Rodríguez, L. E. "Origen y evolución de la papa cultivada. Una revisión". *Agronomía Colombiana*, vol. 28, no. 1, 2010, pp. 9-17, ISSN 0120-9965.

Received: April 14th, 2015
Accepted: November 2th, 2015

Revista Cultivos Tropicales
Instituto Nacional de Ciencias Agrícolas