ORIGINAL ARTICLE

Plantation Times in the Productivity of Garlic in Beds and Bags

Efecto de épocas y métodos de plantación sobre la productividad del ajo

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Annarellis Alvarez-Pinedo[I*], Darién Andrés Hernández-González[II], Dariellys Martínez-Balmori[III], Lucía Fernández-Chuairey[I], Iván Castro-Lizazo[I], Liane Portuondo-Farías[IV], Humberto Izquierdo-Oviedo†[V]

[I]Universidad Agraria de La Habana (UNAH) "Fructuoso Rodríguez Pérez", San José de las Lajas, Mayabeque, Cuba.
[II]Centro de investigación y desarrollo de medicamentos (CIDEM), Plaza de la Revolución, La Habana, Cuba.
[III]Universidad de La Habana, Facultad de Química, Plaza de la Revolución, La Habana, Cuba.
[IV]Instituto de Tecnologías y Ciencias Aplicadas (InSTEC), Plaza de la Revolución, La Habana, Cuba.
[V]Instituto Nacional de Ciencias Agrícolas (INCA), San José de las Lajas, Mayabeque, Cuba.

ABSTRACT: Planting season is a decisive factor for agricultural production success. Yields of garlic culture, one of the vegetables of major demands for Cuban culinary, are very low. There are no reports of recent studies related to garlic productivity based on this factor in the literature of our country. That is why the objective of this work has been the evaluation of different planting times on the productivity of garlic (*Allium sativum* L.) clone 'Criollo Víctor'. The cloves were planted under semi-controlled conditions and in beds during 2019-2020 and 2020-2021 seasons in the months of September, October, November and December. The following indicators were evaluated at different times of growth: sprouting % and plant survival, plant height and the number of leaves. Once harvested (120 days after planting), the indicators evaluated were: equatorial and polar diameter of the bulb, mass of the bulb and cloves, the number of cloves and the yield (t ha^{-1}). The results ratify October, as the optimum planting time, with greater influence of the prevailing climatic conditions on the bulb mass and percentage survival indicators.

***Keywords*:** indicators, planting density, temperature, climatic conditions, yield.

RESUMEN: La época de plantación es un importante factor decisivo en el éxito de las producciones agrícolas. Los rendimientos del cultivo de ajo son bajos, hortaliza de elevada demanda en la culinaria cubana. Estudios recientes, en el país, relacionados con la productividad del ajo no se han encontrado reportados en la literatura consultada, por lo que fue objetivo de este trabajo, evaluar el efecto de las épocas y métodos de plantación en la productividad del ajo (*Allium sativum* L.) clon 'Criollo Víctor'. Se condujeron experimentos que consistieron en la plantación en bolsas de nylon y en canteros, en los meses de septiembre, octubre, noviembre y diciembre, años 2019 y 2020. Se evaluaron los indicadores: porcentaje de brotación, supervivencia de las plantas, altura de las plantas y el número de hojas, y una vez cosechado (120 días después de plantado: DDP) se evaluaron: diámetro ecuatorial y polar del bulbo, masa del bulbo y bulbillos, el número de bulbillos y el rendimiento (t ha^{-1}). Los resultados, para ambas condiciones de plantación estudiadas, ratificaron al mes de octubre como la época óptima de plantación, con mayor peso de las condiciones climáticas imperantes en la masa del bulbo y porcentaje de supervivencia.

***Palabras clave*:** Indicadores, temperatura, condiciones climáticas, rendimiento.

[*]Author for correspondence: Annarellis Álvarez-Pinedo, e-mail: annarellis@unah.edu.cu, annarellisnegra@gmail.com

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INTRODUCTION

Garlic is one of the oldest and most widely used vegetables in traditional Cuban cuisine. In addition, its pharmacological properties for the treatment of toothache, joint pain and insect bites are popularly known.

In Cuba, it only reproduces asexually due, among other factors, to the prevailing climatic conditions Izquierdo Oviedo & Gómez (2012), a factor that also determines that this vegetable is not cultivated throughout the year. It is well documented that temperature is a decisive factor for the formation of the bulbs, with a greater influence on the planting season.

However, studies in our country related to the biological and agricultural productivity of the garlic crop according to the planting season have not been found, despite the global impacts of current climate change, widely recognized in the international and national scientific fields.

The yields of this crop in the country are low, even when compared with other countries that are not large producers of it (FAOSTAT, 2022). Muñoz *et al.* (2010) refer that, for the most used clones, 'Criollo' and 'Vietnamita', yields between 4-9 t ha^{-1} are reported, with an average value of 6 t ha^{-1}, although some producers obtain higher yields of 11 t ha^{-1}, in years with more favorable conditions. Also, Pupo-Feria *et al.* (2016) point out that, in Las Tunas, only average yields of 2,2 t ha^{-1} were obtained, lower than the needs of the population.

Private producers or cooperatives carry out most of garlic production in the country. They use extensive furrows for planting, generally 0,90 m long ridges with double rows at 0,30 m and 4 to 5 cm between plants, with which densities between 44 and 54 plants/m^2 are obtained, that are within the limits recommended in the international literature (Muñoz *et al.*, 2010). It is possible that the low yields of garlic, the fact that it is an annual crop and its high demand are the causes of the annual increase in its price in the national market, so promoting the development of this vegetable in small plots in the context of family, urban or suburban farming could be promising. In this way, the objective of this work was to evaluate the influence of different planting times on the productivity of garlic (*Allium sativum* L.) clone 'Criollo Victor', cultivated in bags and beds in Mayabeque Province.

MATERIALS AND METHODS

Location and Characteristics of the Study Area

The investigation was carried out in areas of "La Jaula" Farm, located at 23º 01 ' North Latitude and 82º 08' West Longitude, in Havana-Matanzas plain, at a height of 130 m.a.s.l., located in San José de las Lajas Municipality, Mayabeque Province, Cuba (ISMET-Cuba, 2022). The experiments were set up during the 2019-2020 and 2020-2021capaigns. In the study area, the average annual temperature was 24,4 °C and fluctuations of minimum and maximum values between 19,6 °C and 30,4 °C; respectively. Relative humidity reached of 79 % and the accumulated value of 202.9 mm in rainfall in the research period, corresponding to 1015,4 % of the annual figure, during the two study campaigns, are presented in Figure 1. The soil of the farm, according to the last version of Genetic Classification of Cuban soils (Hernández *et al.*, 2015), corresponds to a Sialithic brown soil, with an organic matter content of 5,59% and pH value of 7,8.

The plant material used was 'Criollo Víctor', cultivar of garlic (*Allium sativum* L.), from Mayabeque Province, according to its category (basic seed), which was characterized by presenting a globe-flat bulb with a large number of cloves arranged in 4-6 fertile leaves and with a commercial cycle of 120-150 days. The bulbs between 4-6 g in mass were shelled manually after visible sanitary selection (free of symptoms of nematodes, mites and plant pathogenic diseases) (Marrero *et al.*, 2009; Muñoz *et al.*, 2010).

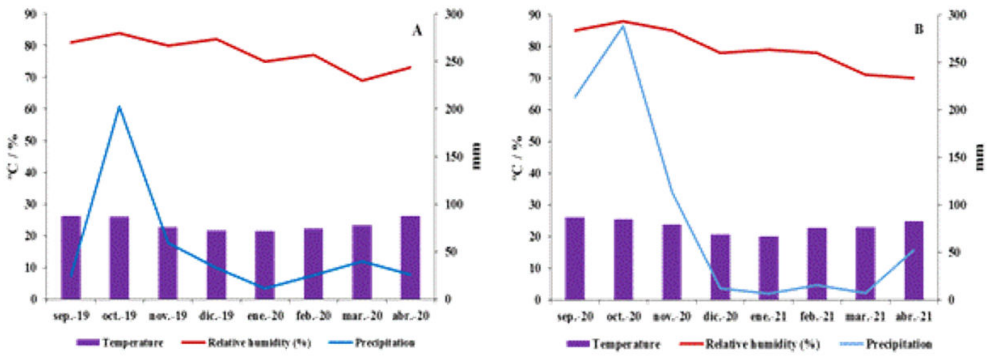


FIGURE 1. Climatological variables: temperature, relative humidity and rainfall during the 2019-2020 (A) and 2020-2021 (B) campaigns.

To study the influence of the planting season, experiments were conducted in bags and beds. In the first case, 240 nylon bags were used (60 bags in each of the months under study: September, October, November and December), with a capacity of 90 cm^3, which were arranged under a black mesh that allows the passage of 70 % of sunlight and in each of them a bulbil was planted. In the second case, three beds were used for each month under study, those that were formed by organic fertilizer (cow manure) homogeneously mixed with the soil before raising them, with a dimension of 20 m long, 1,40 m wide and 0,30 m deep. The cloves were planted in the beds at 4 rows (20 cm between rows and 5 cm between plants), which corresponds to a planting scheme where a planting density of 37 plants m^{-2} is obtained, a value found in the average optimum planting density range (Marrero *et al.*, 2009; Muñoz *et al.*, 2010). The cultural attentions were developed according to the Organoponics and Intensive Gardens Manual (Rodríguez *et al.*, 2010; Zamora, E., 2016). Throughout the experiment, irrigation with a 10 L watering can and the removal of weeds by manual weeding were carried out on alternate days. Each month constituted a treatment, the month of October was the control treatment, since it is considered the optimal month for planting according to the technical instructions for the crop (Marrero *et al.*, 2009; Muñoz *et al.*, 2010).

In both experimental conditions, the indicators evaluated were:

1. Clove sprouting (%), by counting the number of cloves that sprouted with respect to the total planted
2. Plant survival (%), by counting the number of plants that survived with respect to the total planted
3. Plant height (cm), by measuring with a graduated ruler from the base of the bulb to the last extended leaf
4. Number of leaves, by visual counting
5. Equatorial diameter (cm) and polar diameter (cm) of the bulb measured with calipers
6. Bulb mass (g), each individual bulb was weighed on a SARTORIUS brand technical weighing scale
7. Number of cloves, through shelling and counting of cloves per bulb
8. Mass of cloves (g), 20 cloves of each bulb were weighed (10 per treatment).
9. Yield (t ha^{-1})
10. Total bulbs of each treatment were also determined.

For the study of the effect of season and planting methods in the productivity of garlic, beds formed as previously described were used, establishing three different planting distances, including the one established for this crop according to the Technical Instructions (Marrero *et al.*, 2009; Muñoz *et al.*, 2010).

In all the experiments, a completely randomized design was used with three replications for each treatment. For the evaluation of the morphological variables, 10 to 20 bulbous plants per treatment were used. The data were tabulated and graphed using the Microsoft Office Excel tool and statistically processed using the statistical package STATGRAPHICS Plus version 5.0. Descriptive statistics were made for the sprouting and survival variables, where there were 480 observations for the experiment in semi-controlled conditions (bags) and 240 observations for the experiment in beds. The study included the analysis of proportions in these variables corresponding to each month of plantation, as well as the confidence intervals (at 95%). Subsequently, a comparison was made between the means of the proportions of the months of study, assuming as a criterion $p<0.01$ at a level of 99% (Fernandez, 2021). For the study of the remaining variables, a simple classification variance analysis (ANOVA) was used, and the multiple comparison of means was performed using the Tukey test at 95% confidence.

RESULTS AND DISCUSSION

The results of the proportions of sprouting and survival of garlic plants depending on the planting seasons (Table 1) revealed, in all the moments of evaluation and experimental conditions, the month of October, as the one with the highest proportion.

In the experiments conducted with bags, more than 50% of sprouted plants was reached in the month of October, 7 days after planting (DAP). In each month, it was evidenced that the comparison between the mean proportions were not identical (Table 1). At 7 DAP, the mean proportions for the months of September, October and November were significantly different from the general mean; at 14 DAP, only the means for the months of September and October were significantly different, a behavior that was maintained at 120 DDP.

In the case of the results for the conditions in beds, the proportions of sprouting and survival of the plants that were reached were lower, a behavior that could be attributed to the fact that these plants are outdoors, while in semi-controlled conditions the plants were protected by a mesh. At 7 DAP, only the average proportion corresponding to sprouting in the month of October was significantly different from the general average, while at 14 DAP the average proportions of each month reflected that in the months of October and November there were no significant differences (Table 1). The mean survival proportions (120 DAP) in the months of September and October were significantly different from the overall mean at 95% confidence.

TABLE 1. Sprout means and confidence intervals (%) and survival (%) of garlic plants 'Criollo Víctor' cultivated in September, October, November and December, in bags and beds, during 2019-2020 and 2020-2021 campaigns. DDP: days after planted

Treatments	BAGS					
	Sprout(%)				Survival (%)	
	7 DDP		14 DDP		120 DDP	
	Mean	Confidence interval	Mean	Confidence interval	Mean	Confidence interval
September	11,66*	8,72 - 14,61	33,33*	29,01 - 37,65	55,83*	51,28 - 60,39
October	52,50*	47,92 - 57,08	77,50*	73,67 - 81,33	90,83*	88,19 - 93,48
November	45,83*	41,27 - 50,40	63,33	58,92 - 67,75	80,83	77,23 - 84,44
December	25,83	21,82 - 29,85	50,83	46,25 - 55,42	74,17	70,15 - 78,18
Mean	33,96		56,25		75,42	
Esx	2,10		2,20		1,90	
			BEDS			
September	13,33	8,91-17,77	41,66	35,25-48,08	55,00*	48,52-61,48
October	13,33	8,91-17,77	61,66	55,34-67,99	86,66*	82,24-91,09
November	38,33*	32,00-44,66	61,66	55,34-67,99	76,66	71,16-82,17
December	23,33	17,83-28,84	45,00	38,52-51,48	70,00	64,03-75,96
Mean	22,80		52,49		72,08	
Esx	2,68		3,20		2,90	

*Indicates significant difference from the general average to 95% confidence.

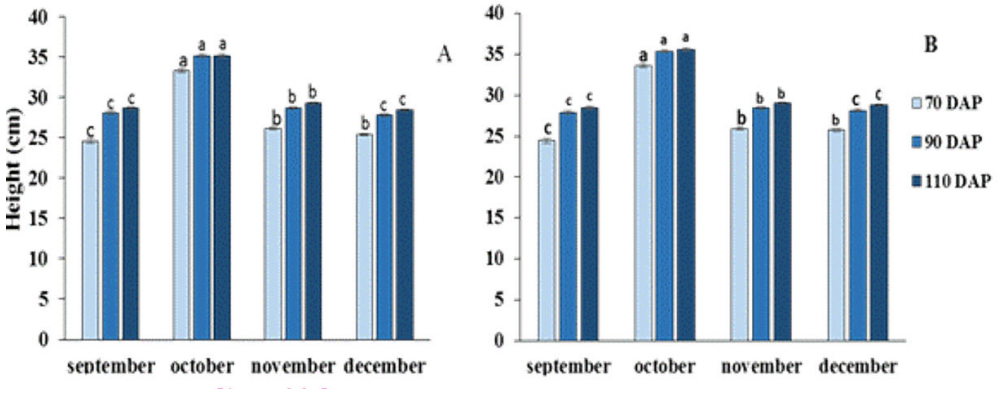
Although sprouting can extend during 20-30 DAP (Rodríguez *et al.*, 2010; Zamora, E., 2016), the fact that they did not reach the maximum sprouting and, consequently, their survival, could be because the cloves had not completed their dormant period (López-Bellido *et al.*, 2016). Its duration depends mainly on genetic factors, as well as on the storage temperature (Burba, 2003). In this work, cloves of bulbs stored at room temperature by a producer in the region were used for planting, in addition to which the storage period was unknown.

The results for the plant height indicator at 70, 90 and 110 DAP, in both experimental conditions, indicated that the crop planted in the month of October originated plants that reached height values significantly higher than the rest of the months.

For both experimental conditions, at 70 DAP significant differences were observed between all treatments, while at 90 DAP the values obtained for this indicator in the months of September and December did not show significant differences between them, a behavior that was maintained at 110 DAP (Figure 2).

Izquierdo Oviedo & Gómez (2012) report a range of values for this indicator for the 'Criollo-9' clone of 28,5-29,5 cm, similar to those found in this work for all months, except the month of October, where the plants reach 35 cm, a value that is below that reported by Soto (2019).

A similar behavior was found in the number of leaves indicator, with values ranging between 5 and 8 leaves per garlic plant (Figure 3), where in all the



(a-c) Different letters represent significant differences between means according to Tukey 95%

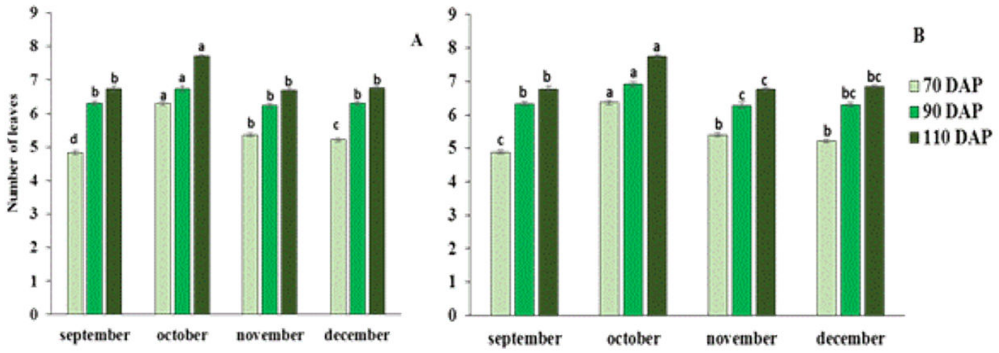
FIGURE 2. Average height (cm) values of garlic plants 'Criollo Víctor' at 70 (CV: 14,33%), 90 (CV: 11,49%) and 110 (CV: 10,8%) days after planted (DDP) in bags (a); and at 70 (CV: 14,30%), 90 (CV: 10,90%) and 110 (CV: 10,66%) DDP in beds (B), during the 2019-2020 and 2020-2021 campaigns.

moments evaluated and both experimental conditions, the values in the month of October were significantly higher when compared to the other months. In the experiments with bags, from 90 DAP there were no significant differences between the months of September, November and December (Figure 3A). In those in beds, at 70 DAP there were no significant differences between the months of November and December, while at 90 and 110 DAP the values obtained in the month of December only differ from those obtained in the month of October (Figure 3B).

The leaf number values found in this work are below those reported for other cultivars (Oliveira *et al.*, 2018; Ayed *et al.*, 2019). Due to environmental conditions or inadequate cultural practices, the number of leaves may increase or decrease in cultivars (López-Bellido *et al.*, 2016). For this clone, no report was found in the consulted literature, of the range of values of this indicator.

The results obtained in the indicators of the bulb of garlic plants evaluated at the time of harvest (120 DAP), are presented in Table 2. For all the indicators, in both experimental conditions, the significantly highest values were found in the month of October, without differences between the other months.

The values of these indicators are lower than other reported in clone 'Criollo-9' Balmori *et al.* (2019) and in 36 garlic accessions from Tunisia (Ayed *et al.*, 2019). However, they correspond to the range of values reported by Benke *et al.* (2018), who worked with 66 garlic accessions collected from different agroclimatic regions of India. The behavior of the bulb indicators was manifested in the cloves (number and mass) presented in Figure 4. In both experimental conditions, no significant differences were observed between the treatments for the indicator number of cloves, while for the indicator clove mass, significant differences were observed. In the cultivation in bags, the mass of the cloves were significantly different between the treatments (Figure 4A), while in beds the mass of the cloves were significantly higher in October, followed by September and November, which were not different among themselves and the lowest value was reached in December. (Figure 4B)

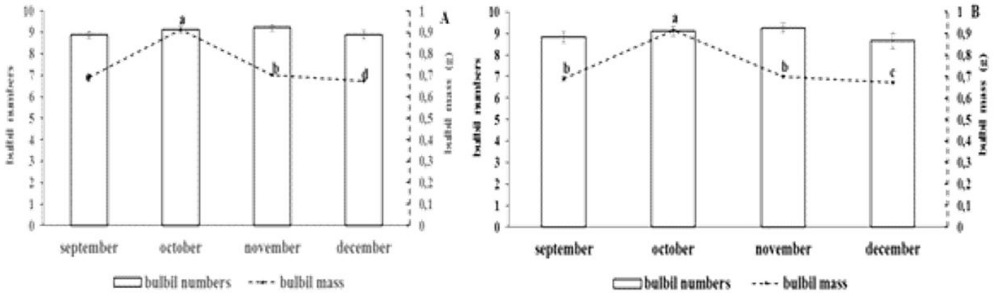


(a-d) Different letters represent significant differences between means according to Tukey 95%

FIGURE 3. Average values of the number of garlic plants 'Criollo Victor' at 70 (CV: 13,43%), 90 (CV: 10,76%) and 110 (9,34%) days after planted (DDP) cultivated in bags (A) and at 70 (CV: 14,89%), 90 (CV: 10,81%) and 110 (10,32%) DDP cultivated in beds (B), during campaigns 2019-2020 and 2020-2021.

TABLE 2. Means of Bulb indicators of 'Criollo Victor' garlic plants cultivated in bags and beds, during the 2019-2020 and 2020-2021 campaigns

Treatments	Equatorial diameter (cm)	Polar diameter (cm)	Bulb mass (g)
	BAGS		
September	2,37 b	1,83 b	5,10 b
October	2,77 a	2,32 a	7,14 a
November	2,38 b	1,83 b	5,18 b
December	2,33 c	1,80 b	5,04 b
Esx	0,01	0,01	0,06
CV (%)	8,50	12,25	17,81
	BEDS		
September	2,39 b	1,84 b	5,14 b
October	2,79 a	2,32 a	7,10 a
November	2,39 b	1,84 b	5,14 b
December	2,34 b	1,82 b	5,08 b
Esx	0,01	0,02	0,06
CV (%)	5,40	5,21	8,80



(a-d) Different letters represent significant differences between means according to Tukey 95 %

FIGURE 4. Average number values (CV: 14,24%) and bulb mass (CV: 13,78%) in the "Criollo Victor" garlic bulbs harvested in beds (A) and number (CV: 11,89 %) and clove mass (CV: 8,30%) in the bulbs of garlic 'Criollo Víctor' harvested in beds (B), during the 2019-2020 and 2020-2021 campaigns.

Benke *et al.* (2018) report a range of clove numbers from 4,40 to 15, with a mean value of 7,84 cloves per bulb, and a range of cloves mass from 0,34 to 1,41 g, with a mean value of 0,79 g, which corresponds to what was found in our work for this clone (Figure 4). However, they are lower than those of Izquierdo Oviedo & Gómez (2012), who report ranges from 35 to 41 for the number of cloves and from 1,35 to 1,41 g for the mass of cloves in the clone 'Criollo-9'.

The results obtained in this work, both in the study carried out in bags and in beds, are well below those found by other authors working with the clone 'Criollo-9' Balmori *et al.* (2019); Izquierdo Oviedo & Gómez (2012); Soto, (2019), It indicates that the cultivar used in this work, clone 'Criollo-Víctor', of which no report was found in the consulted literature, has different characteristics.

Likewise, it could be conditioned by the prevailing climatic conditions (Figure 1). Jawaad *et al.* (2020) refer to the significant impact that the abiotic factors, photoperiod (light) and temperature, have on the morphology and quality of the bulb. In both campaigns, although the temperature values could be considered acceptable for bulb development (21-26 ºC), they are not optimal for the highest growth stage (21-22 ºC), that is, the climatic conditions were somewhat contrary to the requirements of this species. Several authors report that greater growth is favored by low temperatures (< 21 ºC), while bulb development benefits when temperatures increase.

The best yields are achieved when, 25 days after sprouting the cloves, the average daily temperatures remain below 21 ºC for 40 days. These temperatures generally occur in Cuba from December to February (Marrero *et al.*, 2009; Muñoz *et al.*, 2010). However, the results obtained from the yield (Figure 5) of the cultivation of 'Criollo Víctor' garlic, in beds, according to the month of planting, correspond to what has been reported in the literature (Izquierdo Oviedo & Gómez, 2012; Muñoz *et al.*, 2010; Pupo-Feria *et al.*, 2016).

In October, a yield exceeding 2t ha^{-1} was obtained, which is the average reported in our country (Pupo-Feria *et al.*, 2016). The rest of the months show yields of 1,6 t ha^{-1}, in correspondence with the yield range reported for the Criollo clone of 1,5 to 1,7 t ha^{-1} by Muñoz *et al.* (2010) for early plantings (second half of September and first half of October) or late (second half of November and first half of December).

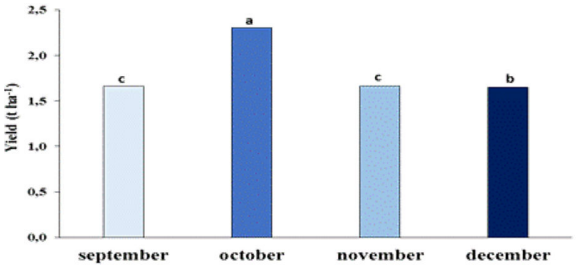


FIGURE 5. Average yield values (t ha^{-1}) of the "Criollo Víctor' garlic crop harvested in September, October, November and December in beds, during the 2019-2020 and 2020-2021 campaigns.

The physiological complexity of garlic is strongly influenced by environmental factors such as temperature and photoperiod according to López-Bellido *et al.* (2016), and the the growth and development of the crop depend on the interaction between these factors (Muñoz *et al.*, 2010; Jawaad *et al.*, 2020). It becomes difficult to relate the results obtained in this work with these factors. However, the results obtained, in the study, both in bags and in beds, confirm the month of October as the most promising time for garlic planting.

CONCLUSIONS

The best season for planting the garlic crop, according to productivity and planting method (bags and beds) corresponds to the month of October.

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Annarellis Alvarez Pinedo, MSc., Profesor Auxiliar, Universidad Agraria de La Habana "Fructuoso Rodríguez Pérez" (UNAH). Autopista Nacional y Carretera de Tapaste km 23$^{1/2}$. CP: 32700. Apartado Postal: 1819. San José de las Lajas. Mayabeque. Cuba,
e-mail: annarellis@unah.edu.cu annarellisnegra@gmail.com; ORCID iD: https://orcid.org/0000-0002-7267-3066
Darién Andrés Hernández González, Centro de investigación y desarrollo de medicamentos (CIDEM). Ave. 26 No. 1605 e/ Boyeros y Puentes Grandes, Plaza de la Revolución, Vedado, La Habana. CP 10400. Cuba,
e-mail: darienhdez97@gmail.com código ORCID iD: http://orcid.org/0000-0003-2428-4792
Dariellys Martínez Balmori, Dr. C., Profesor Titular, Universidad de La Habana, Facultad de Química, La Habana, Cuba,
e-mail: dmbalmori@gmail.com código ORCID: http://orcid.org/0000-0002-8321-8077
Lucía Fernández Chuairey, Dr. C., Profesor Titular, Universidad Agraria de La Habana "Fructuoso Rodríguez Pérez" (UNAH). Autopista Nacional y Carretera de Tapaste km 23$^{1/2}$. CP: 32700. Apartado Postal: 1819. San José de las Lajas. Mayabeque. Cuba,
e-mail: lucia@unah.edu.cu ORCID iD: https://orcid.org/0000-0003-2439-1176
Iván Castro Lizazo, Dr. C., Profesor Titular, Universidad Agraria de La Habana "Fructuoso Rodríguez Pérez" (UNAH). Autopista Nacional y Carretera de Tapaste km 23$^{1/2}$. CP: 32700. Apartado Postal: 1819. San José de las Lajas. Mayabeque. Cuba,
e-mail: ivanc@unah.edu.cu código ORCID: http://orcid.org/0000-0002-6964-5160
Liane Portuondo Farías, Dr. C., Profesor Titular, Departamento de Medio Ambiente. Facultad de Medio Ambiente, Instituto de Tecnologías y Ciencias Aplicadas (InSTEC) - Universidad de La Habana. Avenida Salvador Allende No.1110 e/ Av. Rancho Boyeros y Calzada Infanta, Quinta de los Molinos, Plaza de la Revolución, La Habana, Teléfono: +53 78789857,
e-mail: lianehabana@gmail.com código ORCID: https://orcid.org/0000-0002-2559-8024
Humberto Izquierdo Oviedo † Dr. C., Investigador Auxiliar. Instituto Nacional de Ciencias Agrícolas. Carretera a Tapaste Km. 3 ½ San José de Las Lajas. Mayabeque. Cuba. C.P. 32700,
e-mail: hioviedo@ inca.edu.cu código ORCID: https://orcid.org/0000-0002-0622-2785

Conceptualization: A. Alvarez. Data curation: A. Alvarez, D. M. Balmori, D. A. Hernández Formal analysis: A. Alvarez. D. M. Balmori, H. Izquierdo†, I. Castro, D. A. Hernández, L. B. P. Farías, Fernández, C.L. Investigation: A. Alvarez. D. M. Balmori, D. A. Hernández, I. Castro, H. Izquierdo†. Methodology: A. Alvarez. H. Izquierdo†, D. M. Balmori, I. Castro Supervision: A. Alvarez, D. M. Balmori, H. Izquierdo†, I. Castro Validation: A. Alvarez Roles/Writing, original draft: A. Alvarez Writing, review & editing: A. Alvarez, D. M. Balmori, D. A. Hernández.

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