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Performance of advanced potato clones in different regions, and in organic and conventional production systems

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ABSTRACT

This work aimed to evaluate the performance of potato genotypes in different regions in the organic and conventional production systems. The effect of plant stem development on tuber productivity was also investigated. Experiments were carried out (a) during the2020 spring season in Canoinhas-SC in the conventional production system, (b) in an organic cropping system during the 2021 winter season in Brasília-DF, and in both (c) conventional and (d) organic production systems during the 2022 winter season in Brasília-DF, Brazil. Eleven advanced clones as well as the control cultivars Atlantic (suitable for chips production), Markies and Asterix (suitable for French fries) were evaluated for tuber yield traits, specific gravity, and for the number and length of plant stems. The experimental design was randomized blocks with three replications. A higher productivity of marketable tubers was generally obtained by genotypes with longer stems, *i.e.* taller and more vigorous plants. A higher specific weight of tubers was obtained by genotypes with lower number of stems, which produced a lower number of tubers with higher average mass. Clones with good performance in both conventional and organic production systems were identified. The clones F18-13-03 and F65-13-06 showed high tuber productivity in both systems and a tuber specific gravity equivalent to the controls for French fries Asterix and Markies. The clones F36-13-08, ORG 2156 and F88-11-01 did not show the highest productivity in any of the environments. They showed a high number of tubers per stem and, consequently, the tubers had a reduced average mass. The clones F36-13-08 and ORG 2156 presented a high number of stems, suggesting the possibility of gains in marketable productivity under differentiated sprouting management of the seed tubers.

Keywords: *Solanum tuberosum* L., tuber yield, stem development, specific gravity.

RESUMO

Desempenho de clones avançados de batata em diferentes regiões e nos sistemas de produção orgânico e convencional

Este trabalho teve como objetivo avaliar o desempenho de genótipos de batata em diferentes regiões, e nos sistemas de produção orgânico e convencional, bem como estudar o efeito do desenvolvimento das hastes das plantas na produtividade de tubérculos. Experimentos foram conduzidos (a) na primavera de 2020 em Canoinhas-SC no sistema convencional, (b) no inverno de 2021 em sistema orgânico de cultivo em Brasília-DF e, no inverno de 2022, em sistema convencional (c) e orgânico (d) de cultivo em Brasília-DF, Brasil. Onze clones avançados e as cultivares testemunhas Atlantic (para chips), Markies e Asterix (para fritura em palitos) foram avaliados em relação a caracteres de rendimento de tubérculos, além de gravidade específica e número e comprimento das hastes das plantas. O delineamento experimental foi blocos casualizados com três repetições. Em geral, maior produtividade comercial de tubérculos foi obtida por genótipos com hastes mais compridas, ou seja, plantas mais altas e com maior vigor. Maior gravidade específica de tubérculos foi obtida por genótipos com menor número de hastes, que por consequência proporcionaram a formação de menor número de tubérculos e, com isso, tubérculos com maior massa média. Foram identificados clones com bom desempenho tanto no sistema de produção convencional quanto orgânico. Os clones F18-13-03 e F65-13-06 apresentaram elevada produtividade de tubérculos em ambos os sistemas, e gravidade específica de tubérculos equivalente ou superior às cultivares testemunhas para fritura em palitos, Asterix e Markies. Os clones F36-13-08, ORG 2156 e F88-11-01, embora não tenham apresentado as maiores produtividades considerando-se os diferentes ambientes, apresentaram grande número de tubérculos por haste, o que refletiu em tubérculos com reduzida massa média, com os dois primeiros apresentando também alto número de hastes, havendo para esses a possibilidade de ganhos em produtividade comercial com manejo diferenciado da brotação dos tubérculos semente.

Palavras-chave: *Solanum tuberosum* L., produtividade, desenvolvimento de hastes, gravidade específica.

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Potato (*Solanum tuberosum* L.) is both an economically and a socially important crop in Brazil. In 2022, the Brazilian potato production surpassed 3.8 million tons, cultivated in approximately 116 thousand hectares, with an average yield of 33 t/ha (IBGE, 2022). However, cultivars imported mainly from Europe and North America are the most planted in the Country. They have tubers with good appearance and frying quality; but, in general, they do not suit well the Brazilian growing conditions, especially regarding the shorter photoperiod and the higher temperature. Furthermore, the imported cultivars have a low tolerance to pests and diseases which occur in the Brazilian producing regions (Silva *et al*., 2023). Therefore, large amounts of inputs are required to provide higher yields, which compromises the crop sustainability (Pereira *et al*., 2020). For this reason, there is a great demand for the development of national, more adapted cultivars.

High levels of productivity and tuber quality can be achieved using high doses of pesticides and soluble fertilizers. However, it is possible to grow potatoes less intensively, through organic production systems, in which the concentration of nutrients is lower and only a few natural pesticides are allowed (Djaman *et al*., 2021; Ragassi *et al*., 2020). This way, genotypes that are more resistant to pests and diseases, and efficient in nutrient absorption as well, are more suitable for this type of production system (Ragassi *et al*., 2020).

A remarkable increase in the consumer interest towards organic products was noticed in recent years. Also, the global growth of organic agriculture is notable, especially in terms of the size of the cultivated area and of the diversity of products made available to consumers (Gomes *et al*., 2008; Soares *et al*., 2021). From 2012 to 2019, the number of organic farmers tripled within the records of the Brazilian Ministry of Agriculture, Livestock and Food Supply. Globally, organic agriculture is practiced in an area of 72.3 million hectares and involves at least 3.1 million farmers (Willer *et al*., 2021).

Only a few potato cultivars are recommended for organic cultivation, since they must be rustic and resistant to pests and diseases in order to suit the organic production system. Moreover, they must be efficient on the absorption of nutrients, presenting a satisfactory productivity even in the absence of soluble fertilizers (Nazareno, 2009; Passos *et al*., 2017). The lack of potato seeds produced organically is another bottleneck contributing to the shortage of cultivars suitable for organic cultivation. The production of seeds exclusively for the organic system is rarely viable, as the demand for it is small and seasonal. Moreover, the additional cost for breeding programs to develop cultivars exclusively for the organic system must also be considered (Ragassi *et al*., 2020). In this scenario, a possible solution for such limitations would be to evaluate clones developed in conventional production systems regarding their adaptation to the organic system, looking for genotypes that perform well in both environments. However, studies with potatoes using this approach are scarce. This way, Silva *et al*. (2017) and Ragassi *et al*. (2020) evaluated potato clones developed in the conventional production system and found good adaptation of some genotypes to both systems.

In Brazil, potato is marketed fresh or used for industrial processing, mainly for the production of French fries. In the fresh potato market, the emphasis is on the appearance of the tubers. However, several factors, including a high dry matter content, is crucial regarding the industrial processing, especially for the production of French fries. A higher dry matter content not only contributes to a higher yield during industrialization, but also results in a lower absorption of fat during the frying process (Islam *et al*., 2022).

Regardless of the purpose, achieving optimal tuber yield is a primary objective in any potato breeding program. Among the factors that can positively influence yield, the development of the aboveground part of the plants plays an essential role. Several elements related to the growth of the plant aboveground part are relevant, including both the length and the number of stems. Stem length, as a measure of plant vigor, shows a potential association with overall vigor and suggests a possible link between longer stems and an increase in tuber production (Fantaw *et al*., 2019; Hunde *et al*., 2022). The number of stems per plant is also relevant, with genetic variations influencing it, but it can also be adjusted according to the sprouting stage and management, as well as seed size (Fantaw *et al*., 2019). Investigation of the relationship between these attributes contributes to a deeper understanding of the response patterns of genotypes with respect to the aboveground part growth and tuber yield.

The objective of this work was (a) to evaluate the performance of potato genotypes in different regions, in organic and conventional production systems, and (b) to study the effect of plant stem development on tuber productivity.

MATERIAL AND METHODS

The experiments were carried out in a conventional system in Canoinhas-SC (26º10'38"S, 50º23'24"W, 765 m altitude) in the 2020 spring and in Brasília-DF (15º55'44"S, 48º08'29"W, 999 m altitude) in the winter of 2022. The experiments under organic cultivation were carried out in Brasília-DF (15º56'30"S, 48º08'22"W, 999 m altitude) in the 2021 and 2022 winter harvests.

In Canoinhas, the experiment was implemented on August 5, 2020 and harvested 105 days after planting (DAP), while in Brasília, the experiment under conventional cultivation was implemented on May 19, 2022, with harvest at 110 DAP.

The experiments carried out under organic cultivation, in Brasília-DF, were implemented on May 4, 2021 and May 5, 2022, and harvested at 100 DAP.

The set of 11 advanced potato clones (Tables 1, 2 and 3) comprised eight clones selected in the conventional system coded with the letter "F", one clone selected in the organic production system (ORG 2156) from the potato breeding program of Embrapa, Brazil, one clone selected in the conventional production system by the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI, Brazil) (Epagri 116), and one clone developed in the conventional system by the Centre de Recherche Les Buissons, Canada (CC476). The clones were obtained by the institutions through biparental crosses following four generations of selection at their respective locations. The set of clones was evaluated in comparison to the control cultivars Asterix and Markies, which are widely cultivated for the production of French fries; and Atlantic, widely used for the manufacture of chips in Brazil.

Seed tubers measuring 40-50 mm in diameter were stored for eight months in a cold chamber (3.5±0.5°C) in all experiments, standardized to ensure a better comparison between experiments and to ensure adequate sprouting (Silva & Lopes, 2016). The seeds for the 2021 experiment came from the 2020 Canoinhas crop, and those for the 2022 experiments came from the 2021 Brasília experiment.

A randomized block design with three replications was used for all experiments. The plots in Canoinhas had two rows with 10 plants each, while in Brasília they had single rows of 10 plants, both in the conventional and in the organic systems. The plants were spaced 0.80 m between rows and 0.30 m between plants within each row in all experiments.

In the Canoinhas experiments, fertilizers were applied in the planting furrow at doses of 120 kg/ha N, 420 kg/ha P_2O_5 and 240 kg/ha K_2O, using the formula NPK 04-14-08. In Brasília, in the conventional system, fertilizers were applied to the planting furrow with doses of 190 kg/ha N, 420 kg/ha P_2O_5 and 350 kg/ha K_2O. In the organic system, 28,750 kg/ha of organic compost was applied. The organic compost used as planting fertilizer was prepared with poultry manure, a mixture of grasses (palisade grass and elephant grass) and enriched with thermophosphate. The macro and micronutrient composition of the compost was N = 14.9 g/kg; P = 17.5 g/kg; K = 16.6 g/kg; Ca = 63.2 g/kg; Mg = 10.2 g/kg; S = 6.9 g/kg; Cu = 240.0 mg/kg; Zn = 295.0 mg/kg; Fe = 28,032 mg/kg; Mn = 700.2 mg/kg; and B = 59.8 mg/kg. For topdressing, a Bokashi-type bran compost was used at a dosage of 200 g/m applied at 25 DAP. The bran compost was manufactured with the following components: poultry bed litter, limestone, castor bean cake, wheat bran, bone meal, ash or charcoal, milk, decomposing microorganisms (EM), sugar, and water. The total contents of macro and micronutrients in the bran compost were: N = 23.9 g/kg; P = 25.3 g/kg; K = 21.3 g/kg; Ca = 74.8 g/kg; Mg = 23.4 g/kg; S = 6.6 g/kg; Cu = 462.6 mg/kg; Zn = 554.4 mg/kg; Fe = 5.2 mg/kg; Mn = 722.0 mg/kg; B = 59.0 mg/kg and 1,250 kg/ha of thermophosphate (18% P_2O_5) (Couto *et al*., 2008). Cultural and phytosanitary treatments followed the recommendations of the respective regions and production systems (Silva & Lopes, 2016).

The total accumulated rainfall was 355, 8.33, 12.86 and 4.90 mm, the average minimum temperatures were 12.70, 15.64, 15.38 and 14.25°C, and the average maximum temperatures were 25.11, 29.82, 30.61 and 29.99°C, for Canoinhas in 2020, Brasília under conventional system in 2022, Brasília under organic system in 2021 and Brasília under organic system in 2022, respectively. For Canoinhas, no irrigation was done, while for Brasília, it was carried out maintaining the soil at the field capacity.

The following agronomic traits were evaluated: average number of stems per plant and average height of the longest stem of the plants, at 70 days after planting in all experiments, except in the organic system in 2021. The tubers were classified as marketable according to the transverse diameter (>45 mm) to obtain the mass of marketable tubers (kg/plot). The average mass of tubers was obtained by the ratio between the total mass of tubers and the total number of tubers in each plot. The average mass of the tuber was not evaluated in the organic system. The relationship between the total number of tubers and the average number of stems of the plots was also determined. The specific gravity was also evaluated in samples of 3630 g of marketable tubers from each plot, in the experiments of Canoinhas and of the organic system in Brasília. The specific gravity was estimated using a hydrometer from the Snack Food Association (Arlington, VA, USA) according to Silva *et al*. (2020b).

Tuber mass data were converted to t/ha and subjected to individual and joint analysis of variance, followed by grouping of means using the Scott & Knott test and the simple correlation between traits. The environmental coefficients of variation were also calculated, obtained by the ratio between the standard deviation and the mean, in percentage. Statistical analyses were carried out using the Genes software (Cruz, 2016).

RESULTS AND DISCUSSION

The joint analysis of variance showed significant differences ($p<0.05$) among the genotypes for all the characteristics evaluated in this study. A significant genotype x environment interaction was observed for almost all the characters, indicating that, in general, the genotypes performed distinctly in the environments studied, except for specific gravity. For this character, the interaction was not significant. The environment effect was significant for most of the characters, except for specific gravity, height of the longest stem and for the ratio between the total number of tubers and the number of stems.

The coefficients of environmental variation (CV) were lower than or around 30% for all traits, in all experiments, indicating good precision, as quantitative traits are highly influenced by the environment (Silva *et al*., 2020b).

For the yield of marketable tubers (Table 1), which is the most important productivity trait, the clones CC476 and F119-12-01 presented the highest values in Canoinhas, on average 31.02 t/ha, which was equivalent to the control cv. Atlantic and approximately 37% higher than the average yield obtained by the set of genotypes. The clones F18-13-03, F65-13-05 and F88-11-01 also stood out, with yields around 24 t/ha, not differing from the second most productive control, cv. Markies. Most of the remaining clones were superior in comparison to Asterix regarding the productivity of marketable tubers, except Epagri 116. In Brasília, under the conventional system, the cv. Atlantic was superior in comparison to all genotypes (46.44 t/ha), the clone F65-13-06, with 38.29 t/ha, was equivalent to Markies, and most of the remaining genotypes were superior in comparison to Asterix, except Epagri 116 and ORG 2156. Under the organic system, the clones F18-13-03 and F65-13-06 stood out, with a productivity of marketable tubers 54.79% higher than the control cultivars, in average. However, in the organic system in 2022, the clones F59-14-39, F06-13-01, and F65-13-05 also stood out, presenting an average approximately 52% higher than the control cultivars. The clones CC476, F119-12-01, and ORG 2156 presented yields ranging from 20.10 to 24.35 t/ha, equivalent to the most productive cultivars, Asterix and Markies. In general, Epagri 116 was inferior to the other genotypes, and almost all other clones were superior or equivalent to the control cultivars considering the set of environments, except ORG 2156, F06-13-01, and F36-13-08, which did not stand out in the set of environments. The clones F36-13-08 and F88-11-01 did not perform well in any year in the organic production system, with an average of 21.19 t/ha.

According to Pádua *et al*. (2010), for the production of French fries, the ideal specific gravity of the tubers should be between 1.070 and 1.097. For the production of chips, a higher content is required, though, between 1.077 and 1.097. Observing the classification of the genotypes regarding specific gravity, only the clone Epagri 116 was inferior. The clones CC476, F119-12-01 and F18-13-03 were equivalent to the cultivars Asterix and Markies, which are recommended for the production of French fries, and all the other clones were equivalent to the cultivar Atlantic, which is recommended for the production of chips (Table 1).

Regarding the average tuber mass, which was determined only in the conventional cultivation system (Table 2), the clone CC476 performed well in both locations (Canoinhas and Brasília), averaging 121.12 g. In Canoinhas, the clone F59-14-39, with 103.27 g, was equivalent to the cultivar Atlantic (95.95 g), and produced, on average, the heaviest tubers. All other genotypes presented tubers with an average mass not different from cultivars Asterix and Markies. In Brasília, the clone F65-13-05 (145 g) also stood out, with an average mass equivalent to the controls Atlantic (112.01 g) and Markies (104.47 g). Clones F119-12-01 (89.96 g) and F59-14-39 (79.05 g) were superior in comparison to Asterix (44.85 g).

The number of stems per plant varies according to genetic differences, but it can be adjusted according to the sprouting stage and seed size, with larger and more sprouted seeds tending to produce a greater number of shoots and, consequently, stems. In addition, genotypes with a higher dry matter content also tend to have a poorer sprouting (Mustefa *et al*., 2017). The clone F18-13-03 was grouped within the group of highest average number of stems in the three environments evaluated (6.67 to 17.33). The clone F59-14-39 (3.00 to 4.33) was grouped with Atlantic (3.00 to 6.67), within the group presenting the lowest number of stems in all environments. This information is important to be compared to tuber yield, since, for example, the clone F18-13-03, in addition to presenting a high number of stems, also presented a reduced average mass of tuber and was not grouped among those with the highest marketable yield, indicating that a differentiated management of seed sprouting should be studied.

In general, potato plants with more stems tend to produce a greater number of tubers, which may contribute to a higher productivity (Fantaw *et al*., 2019). However, plants with a high number of tubers also tend to produce smaller tubers (Fantaw *et al*., 2019; Silva *et al*., 2020a), so it is important to achieve a balance between such characteristics. In general, the relation of number of tubers per number of stems was close to 1.50. The clones F36-13-08, ORG 2156, and F88-11-01 were grouped among those with the highest number of tubers in relation to the number of stems in the two environments tested. The clones F36-13-08 and ORG 2156, in general, also presented a high number of stems per plant, and reduced average mass and marketable yield, indicating the necessity for differentiated sprouting management. However, the clone F88-11-01 showed a different behavior, not having, in general, a high number of stems, but a large number of tubers per stem, which also impacted productivity measurements, indicating that, for this clone, differentiated seed management would not produce favorable results.

Table 1. Average marketable tuber yields of 11 advanced potato clones and three cultivars, in the 2020 spring harvest in the conventional production system in Canoinhas-SC, in the 2022 winter harvest in the conventional system in Brasília-

DF, and in 2021 and 2022 winter harvests in the organic production system, in Brasília-DF, Brazil; specific gravity, in the average of data from the 2020 spring harvest in the conventional production system in Canoinhas-SC, and in the 2021 and 2022 winter harvests in the organic production system in Brasília-DF, Brazil. Canoinhas and Brasília, Embrapa, 2020/2022.

Genotypes	Marketable tuber productivity (t/ha)				Specific gravity*
	Canoinhas Conv. System 2020	Brasilia Conv. System 2022	Brasilia Org. Syst. 2021	Brasilia Org. Syst. 2022	Canoinhas Conv. System 2020 and Brasilia Org. Syst. 2021 and 2022
CC476	32.67 aA	30.66 cA	26.95 bA	24.35 dA	1.078 b
Epagri 116	10.72 dB	8.23 eB	23.90 bA	9.48 eB	1.064 c
F06-13-01	18.57 cB	29.15 cA	25.83 bA	26.49 cA	1.088 a
F119-12-01	29.37 aA	30.12 cA	31.48 bA	21.10 dB	1.080 b
F18-13-03	23.93 bC	29.99 cB	43.76 aA	33.49 bB	1.079 b
F36-13-08	21.60 cA	25.77 cA	27.33 bA	15.80 eB	1.085 a
F59-14-39	20.75 cB	25.79 cB	23.56 bB	40.35 aA	1.090 a
F65-13-05	23.86 bA	28.10 cA	32.91 bA	25.86 cA	1.088 a
F65-13-06	20.32 cC	38.29 bA	42.70 aA	31.81 bB	1.086 a
F88-11-01	23.93 bA	27.23 cA	28.50 bA	13.14 eB	1.089 a
ORG 2156	18.80 cA	21.39 dA	26.73 bA	20.10 dA	1.092 a
Asterix	13.81 dC	21.08 dB	30.72 bA	21.46 dB	1.078 b
Atlantic	32.82 aB	46.44 aA	25.70 bC	17.24 eD	1.091 a
Markies	26.51 bB	38.58 bA	29.48 bB	22.45 dB	1.080 b
Averages	22.69 B	28.63 A	29.97 A	23.08 B	1.083
CV (%)	11.69	14.72	16.96	20.75	0.38

Averages followed by the same lowercase letter in the column and uppercase letter in the row belong to the same group by the Scott & Knott test at 5% probability. CV (%) = coefficient of environmental variation. *The genotype x environment interaction was not significant for specific gravity.

The length or height of the stems (Table 3), as a measure of plant stature, is related to plant vigor. A relationship exists between plants with longer stems and a higher tuber productivity (Fantaw *et al*., 2019; Hunde *et al*., 2022). The clone F65-13-06 (44.33 to 54.00 cm) and the cultivar Markies (48.33 to 57.00 cm) were grouped among the genotypes with the longest stems in all environments. ORG 2156 also presented higher plants in both cultivation systems in Brasília (50.00 to 57 cm), and the clones CC476 (46.67 to 55.00 cm) and F119-12-01 (43.33 to 65.00 cm) had higher plants in both environments under the conventional system.

The relationship between the traits and their magnitude can be better understood with the correlation analysis between the traits (Table 4). A higher marketable tuber productivity was related to a higher average tuber mass, as expected. Nevertheless, a higher marketable tuber productivity was also related with a greater length of the largest stem, confirming a relationship between higher plants and a higher tuber productivity in this set of genotypes. These findings are in agreement with the information present in the literature (Fekadu *et al*., 2013; Fantaw *et al*., 2019; Pereira *et al*., 2020; Silva *et al*., 2020a; Hunde *et al*., 2022).

Higher plants, in general, also produced a higher number of tubers. The total number of tubers was negatively correlated with the average tuber mass, as expected. The total number of tubers was also correlated with a greater number of stems, in agreement with the literature (Fantaw *et al*., 2019; Silva *et al*., 2020a).

A higher specific gravity was related to higher average tuber mass, a lower number of stems and a higher ratio of number of tubers per stem. The correlation between specific gravity and the number of stems agrees with the literature (Getahun *et al*., 2020; Hunde *et al*., 2022) and can probably be explained by the fact that, in general, genotypes with a higher dry matter content present greater tuber-seed dormancy. Consequently, the genotypes with a higher dry matter content present poorer sprouting and, therefore, lower number of stems (Mustefa *et al*., 2017). The opposite is also true. A higher number of stems and, consequently, a higher number of tubers, are related to lower average tuber mass, promoting greater competition for photoassimilates, due to the greater strength of sinks and, consequently, lower specific gravity (Shayanowako *et al*., 2015).

Table 2. Average tuber mass and number of stems per plant of 11 advanced potato clones and three cultivars, in the 2020 spring harvest in the conventional production system in Canoinhas-SC, and in the 2022 winter harvest in the conventional system in Brasília-DF, Brazil. Canoinhas and Brasília, Embrapa, 2020/2022.

Genotypes	Average tuber mass (g)		Number of stems per plant		
	Canoinhas Conv. Syst.	Brasilia Conv. Syst.	Canoinhas Conv. Syst.	Brasilia Conv. Syst.	Brasilia Org. Syst.
	2020	2022	2020	2022	2022
CC476	91.15 aB	151.09 aA	8.00 eA	4.67 bB	2.00 cC
Epagri 116	40.41 bA	64.41 dA	6.00 fA	5.00 bA	7.00 aA
F06-13-01	39.09 bA	62.22 dA	9.67 dA	7.00 aB	5.67 bB
F119-12-01	52.02 bB	89.96 cA	10.00 dA	8.00 aA	7.67 aA
F18-13-03	39.83 bA	52.25 dA	17.33 aA	6.67 aB	8.67 aB
F36-13-08	51.90 bA	53.83 dA	5.00 fA	6.33 bA	5.33 bA
F59-14-39	103.27 aA	79.05 cA	4.33 fA	4.33 bA	3.00 cA
F65-13-05	51.24 bB	113.34 bA	5.67 fA	6.00 bA	4.33 bA
F65-13-06	59.37 bB	145.00 aA	12.33 cA	6.00 bB	4.33 bB
F88-11-01	36.45 bA	60.66 dA	8.00 eA	7.33 aA	8.67 aA
ORG 2156	40.02 bA	58.90 dA	5.67 fA	4.33 bA	4.67 bA
Asterix	30.75 bA	44.85 dA	14.67 bA	5.33 bB	2.33 cC
Atlantic	95.01 aA	112.01 bA	6.67 fA	5.33 bA	3.00 cB
Markies	61.95 bB	104.47 bA	10.33dA	9.00 aA	3.00 cB
Averages	56.60 B	85.15 A	8.83 A	6.10 B	4.98 B
CV (%)	16.45	22.42	17.95	23.36	18.16

Averages followed by the same lowercase letter in the column and uppercase letter in the row belong to the same group by the Scott & Knott and t tests at 5% probability, respectively. CV (%) = coefficient of environmental variation.

Table 3. Total number of tubers/number of stems and height of the longest stem of 11 advanced potato clones and three cultivars, in the 2020 spring harvest in the conventional production system in Canoinhas-SC, and in the 2022 winter harvest in the conventional and organic production systems in Brasília-DF, Brazil. Canoinhas and Brasília, Embrapa, 2020/2022.

Genotypes	Total number of tubers/number of stems		Height of largest stem (cm)		
	Canoinhas Conv. Syst.	Brasilia Conv. Syst.	Canoinhas Conv. Syst.	Brasilia Conv. Syst.	Brasilia Org. Syst.
	2020	2022	2020	2022	2022
CC476	1.24 bA	1.11 bA	55.00 aA	46.67 aA	46.33 bA
Epagri 116	1.22 bA	0.60 bA	30.67 bA	20.00 bB	37.00 bA
F06-13-01	1.46 bA	1.67 aA	51.67 aA	30.00 bB	39.33 bB
F119-12-01	1.58 bA	1.05 bA	65.00 aA	43.33 aB	47.67 bB
F18-13-03	0.91 bB	2.12 aA	55.00 aA	33.33 bB	46.67 bA
F36-13-08	2.40 aA	1.88 aA	31.67 bA	38.33 aA	45.00 bA
F59-14-39	1.24 bB	1.95 aA	36.67 bA	43.33 aA	40.00 bA
F65-13-05	2.36 aA	1.08 bB	38.33 bA	41.67 aA	47.67 bA
F65-13-06	0.75 bA	1.06 bA	53.33 aA	43.33 aA	54.00 aA
F88-11-01	2.26 aA	1.52 aB	53.67 aA	41.67 aA	43.00 bA
ORG 2156	2.18 aA	2.16 aA	45.00 bA	50.00 aA	57.00 aA
Asterix	0.83 bB	2.10 aA	49.67 aA	46.67 aA	47.33 bA
Atlantic	1.39 bA	2.01 aA	45.00 bA	46.67 aA	36.67 bA
Markies	1.11 bA	0.99 bA	55.33 aA	48.33 aA	57.00 aA
Averages	1.49 A	1.52 A	47.57 A	40.95 A	46.05 A
CV (%)	28.95	25.45	7.27	18.12	21.97

Averages followed by the same lowercase letter in the column and uppercase letter in the row belong to the same group by the Scott & Knott and t tests at 5% probability, respectively. CV (%) = coefficient of environmental variation.

Table 4. Simple correlation between traits across all crops and cropping systems for 11 advanced potato clones and three cultivars. Canoinhas and Brasília, Embrapa, 2020/2022.

	TCM	NTT	MMT	N°H	NTT/H#	AMH

NTT	0.22					
MMT	0.60*	-0.61*				
N°H	0.05	0.41*	-0.21			
NTT/H#	0.02	0.59*	-0.39*	-0.41*		
AMH	0.44*	0.35*	0.19	0.29	-0.01	
GE	0.15	0.03	0.39*	-0.32*	0.41*	-0.03

TCM = mass of marketable tubers; NTT = total number of tubers; MMT = average mass of tubers; N°H = number of stems; NTT/H#: total number of tubers/number of stems ratio; AMH: height of the longest stem; GE: specific gravity. *significant at 5% by t-test.

In this study, clones with a good performance were identified in both conventional and organic production systems. Similarly, Silva *et al.* (2017) and Ragassi *et al.* (2020) evaluated potato clones developed in a conventional system and found that some of them adapted well to both cultivation systems, although the vast majority performed better in specific environments, highlighting the difficulty of identifying genotypes adapted to cultivation in both systems.

It was possible to verify in this study that, in general, a higher marketable tuber productivity was obtained by genotypes with longer stems, i.e., taller and more vigorous plants. A higher tuber specific gravity was obtained by genotypes with fewer stems, which, consequently, provided the formation of fewer tubers and, therefore, tubers with higher average mass. The clones F18-13-03 and F65-13-06 presented a high tuber productivity in both conventional and organic production systems, and tuber specific gravity equivalent to or higher than the control cultivars for French fries Asterix and Markies. The clones F36-13-08, ORG 2156 and F88-11-01 did not present the highest productivity in the set of environments, and both presented a large number of tubers per stem, which reflected in tubers with reduced average mass. The clones F36-13-08 and ORG 2156 presented a large number of stems, with the possibility of gains in marketable productivity with differentiated management of the sprouting of seed tubers.

AUTHORS' CONTRIBUTIONS

Erciso MP Rodrigues, Agnaldo DF Carvalho, Anderson F Oliveira and **Carlos F Ragassi:** conducted the essays and evaluations in Brasília-DF**; Arione da Silva Pereira, Antonio C Bortoletto, Nelson P Feldberg** and **Giovani O Silva:** conducted the essays and evaluations in Canoinhas-SC. All authors contributed to writing this paper.

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DATA AVALAIBILITY

Data will be made available upon request to the corresponding author.

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