Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 29 Fevereiro 2024
https://doi.org/10.14295/CS.v15.4009

Profitability and efficiency of conduction systems and optimal tomato density for fresh consumption

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Abstract

This study evaluated the productivity and economic profitability of cultivation systems for the table market. A hybrid tomato cultivar, Fascínio was grown in 12 cultivation systems of the "half stake", "open V", and "low" types, with four spacings–0.2, 0.3, 0.4, and 0.5 m between plants and 1.5 m between rows. Eleven fruits were harvested at the mature stage, and the productive (total, commercial, and non-commercial productivity, percentage of losses, and types of damage) and economic (production cost, revenue, and profit) parameters were evaluated. The half-stake and low (both with 0.2 m spacing) cropping systems showed the highest total yields (179 t ha^{-1}), differing from the open V (154.4 t ha^{-1}) and half-stake (0.2 m spacing) systems at higher commercial productivity (158.1 t ha^{-1}). With a production cost below 100 thousand R$ per hectare and a profitability index above 58%, the half-stake and low (0.2 m spacing) cultivation systems proved to be more productive and economically efficient than the open V system, fulfilling the requirements of tomato growers. The creeping system (0.2 m spacing) had the highest percentage of losses (22%) due to non-marketable fruits; Based on damage nature, the half-stake system tomatoes showed black backgrounds and the open and creeping systems showed tomato locules affected by pests.

Keywords: cultivation systems, half-stake, planting density, *Solanum lycopersicum*, tutoring

Introduction

The tomato fruit (*Solanum lycopersicum* Mill.) is the most widely consumed vegetable worldwide. Globally, Brazil is the ninth largest tomato producer with the third highest productivity (FAOSTAT, 2019).

The demand for tomato fruits is rising because of their pleasant taste, aroma, and their nutritional composition, which is rich in vitamins, minerals, and various carotenoid pigments that act as antioxidants, helping prevent diseases such as cancer (Tan et al., 2019).

The tomato is cultivated in all states of the country (IBGE, 2018), and the states of Goiás, São Paulo, and Minas Gerais contribute to 60% of national production, with 63.4% referring to the production of table tomatoes and 36.6% for industrial processing (Matos, et al., 2012). Most table tomato cultivation in Brazil is performed using cultivars of indeterminate habits that require a greater input and cultural practices, raising production costs that can exceed 100,000 R$ per hectare (HORTIFRUTIBRASIL, 2016).

Determinate growth of tomatoes has benefits compared to indeterminate growth, as it reduces cultural treatments and expenses. In addition, efficient culture treatments such as staking, plant population, and distribution can directly influence tomato development, increase production, and reduce spacing can optimize productivity (Almeida et al., 2015).

Thus, one way to improve tomato production efficiency is to use techniques and cultural treatments that maximize field production, that act directly on input reduction. Efficient production systems increase production and reduce production expense (Almeida et al., 2015). Therefore, to ensure the viability of tomato cultivation, a broad assessment of costs at all stages of the production process must be conducted, which is fundamental for a rural producer in assessing options and

Received: 22 May 2022
Accepted: 10 April 2023

making decisions.

Thus, in this study, we evaluated the productivity and economic profitability of the association of cultivation systems for the table market.

Material and Methods

The experiment was performed in the Nova Mutum municipality, in the mid-north region of Mato Grosso, at south latitude: 13° 05' 04" and west longitude: 56° 05' 16", from March to September 2018, with an average temperature of 24°C. The soil in this region is described as dystrophic red-yellow latosol (EMBRAPA, 2013).

The cultivation systems were formed by the association of three conduction systems and four spacings between plants: 'half-stake' (plants conducted vertically using plastic ribbons horizontally every 0.2 m, bamboo every 3 m, and beams of wood every 11 m), 'open V' with siding screens (plants conducted randomly at angles of 75°, supported by a siding-type screen on the sides in a "V" format, bamboo every 4 m, and beams every 11 m, along the entire side); and 'cracking' or mulching (creeping plants without a tutor on white polyethylene films (50 mm thick) in beds 0.2 m high and 1.20 m wide); the four spacings between plants were 0.2, 0.3, 0.4, and 0.5 m in single rows for all production systems. Between rows, spacing of 1.5 m was used, generating populations of 33,333; 22,222; 16,666 and 13,333 plants per hectare. The 12 treatments were arranged in randomized blocks in a 3 × 4 fashion, with four replicates and 48 plots. Each plot contained four rows, two central rows, and eight plants for evaluation.

Fertilization was performed based on soil analysis, following the recommendation for tutored tomatoes (Ribeiro et al., 1999), using 200 kg ha^{-1} urea, 300 kg ha^{-1} triple superphosphate, 300 kg ha $^{-1}$ potassium chloride, and 5 t ha^{-1} chicken bedding. Plant fertilization was conducted in a furrow using 10% urea, 100% simple superphosphate, and 10% potassium chloride; the other quantities were added in weekly installments via fertirrigation with ammonium sulfate and potassium nitrate.

The seedlings were produced in polystyrene trays with 128 cells/tray, filled with VIVATO® commercial substrate in one seed per cell under a protected environment (structure of 3 m height with a lantern and transparent plastic cover of 150 μm thickness) and shading screens 50% on the sides. Field transplants were performed 25 days after sowing, when they had three to four definitive leaves (Alvarenga, 2013). The hybrid cultivar, Fascínio, was used, which has determined growth, double aptitude, and Italian type fruits. A total of 768 seedlings were distributed over an area of 425.6 m².

Irrigation was performed via dripping, and the suction pressure of the soil was verified using tensiometers to determine the irrigation levels. Phytosanitary control of pests and diseases was performed as recommended by Alvarenga (2013), and the area was weeded to control invasive plants. Pruning or thinning was not performed in any treatment.

Fruit harvesting began 75 days after sowing and lasted more than 90 days, totaling 11 harvests (June to September 2018). Productive efficiency and profitability of each treatment was evaluated separately.

Productive analysis of cropping systems

The fruits were harvested when in a ripe red color according to the Ministry of Agriculture, Livestock, and Food Supply (MAPA, 2002). The following parameters were considered: total productivity (t ha^{-1}), commercial productivity (t ha^{-1}), non-commercial productivity (mass of non-marketable fruits), percentage of losses (%), and damage by classification (damage caused by pests, scalding, open locules, black backgrounds, and zipper) (MAPA, 2002; PBMH, 2003).

Economic analysis of cropping systems

Costs and operations were separated into the following categories: effective operating costs (inputs and labor; EOC) and indirect costs (IC), which formed the total operating (TOC) and production (TCO) costs. The methodology from the Institute of Economics Agricultural in São Paulo was followed (Matsunaga et al., 1976; Araújo & Araújo, 2008).

According to Martin et al. (1998), the main costs involve classifications; the EOC is equivalent to the sum of costs incurred in tomato cultivation in the different systems, adding the expense of inputs, and manual and mechanized operations:

a) Inputs: Includes all consumables: seeds, fertilizers, insecticides, and physical structures.

b) Mechanized operations: (R$/ha): Costs associated with harrowing and mulching installation.

c) Manual operations (R$) per man per day (hd): Sowing, transplanting, driving, and harvesting.

Application of fungicides, insecticides, planting, and topdressing fertilizers were identical for all treatments.

For economic analysis, the following evaluations were considered:

a) Gross Revenue (RB): Expected revenue for activity and yield per hectare at a predefined selling price (tomato productivity in t ha^{-1} × sale price per ton by the producer estimated at R$ 1,500.00 t ha^{-1}).

b) Operating Profit (OP): The difference between RB and TOC per hectare of tomatoes.

c) Profitability Index (PI): The ratio between LO and RB, in percentage–IL= (LO/RB) × 100). It demonstrates the available rate (%).

d) Gross Margin (GM): Ratio of RB to TOC (GM = (GR - TOC)/TOC × 100)), availability (%) to cover other fixed costs and risks.

e) Leveling Point (production): ratio of the quantity of product required to pay the TOC (production = TOC/commercialization value).

f) Breakeven point (Price): determines the price at which tomatoes are sold to pay production costs (Price = TOC/production).

Statistical analysis

The results were subjected to variance analysis, and the significant differences were compared by the Scott□Knott test at the 5% probability level for the qualitative characteristics (driving systems) and for the qualitative ones (spacing between plants) polynomial regression using the SISVAR 4.0 program (Ferreira, 2010)

Results and Discussion

The determinate growth tomatoes evaluated in the 12 cultivation systems had high productivity, in many cases above 100 t ha^{-1}. The highest total and commercial productivity was observed in denser crops, with commercial productivity superior to 139 t ha^{-1} (**Figure 1**).

The highest commercial yields were obtained in the half-stake cultivation systems with spacing of 0.2 m at a value of 158.1 t ha^{-1}. The open V and creeping systems with 0.2 m spacing provided a commercial yield of 139.0 t ha^{-1} and 139.6 t ha^{-1}, respectively, statistically differing from the other systems.

In denser crops, productivity was higher and an increase in population increased productivity per area. The increase in plant population in the studied systems ranged from 13,333 to 33,333 plants per hectare.

For "*in natura*" consumption, tomato producers use plants of indeterminate growth, due to the increase in productivity per hectare (Piotto and Peres, 2012); however, plants of determinate growth can be potentially used by introducing changes in traditional productive systems with success in the table tomato culture.

The conduction system directly influences productivity and may facilitate phytosanitary operations and other cultural practices. In tomatoes with indeterminate growth, Wamser et al. (2012) obtained productivity between 135.1 and 161.1 t ha^{-1} using vertical and 'V' cultivation systems. While using single and double row cultivation, a obtained productivity approximately 120 t ha^{-1} was obtained. Increased density of plants results in greater productivity; however, significant increase in competition for resources can result in reduced productivity or the production of smaller fruits.

The yields obtained in this study were higher than those of previous studies, which mostly employed indeterminate tomato plants. Heine et al. (2015) obtained productivity ranging from 66 to 100 t ha^{-1}; Shirahide and Melo (2012) obtained a yield range of 94.5 and 94.9 t ha^{-1} in the bamboo and ribbon systems, and Schwarz et al. (2013) utilized in ground cultivation over mulching, obtaining yields between 28.8 and 49.4 t ha^{-1}. Thus, the cultivation of tomatoes with specific habits can increase productivity.

Determinate tomato plants were primarily produced for 60 days; however, in this study the

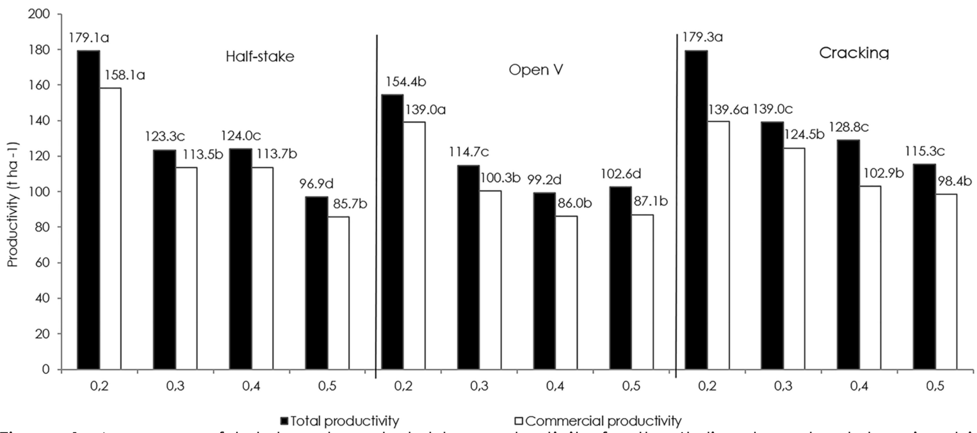

Figure 1. Averages of total and marketable productivity for the Italian tomato determined in different cropping systems.
**Averages followed by the same lowercase letter in the column do not differ from each other based on the Scott-Knott test results at 5% probability.

evaluated systems enabled the determinate tomato plant production for more than 90 days (**Figure 2**), with 11 harvests performed. Fruit production in the half-stake and open V-cultivation systems had a greater distribution throughout the harvests, allowing an increase in the production period and period of fruit supply in the market. Conversely, the creeping system had greater homogeneity in maturation, concentrating fruit production and harvesting (Figure 2).

Cultivation systems directly influence tomato production (Almeida et al., 2015), indicating that different production systems can be adapted for consumption-directed production. Thus, production systems with optimal cultural practices provide significant results in vegetative development, prolonging the plant cycle (Antônio et al., 2017), extending the harvest period, and increasing productivity (Ogundare et al., 2015). Thus,

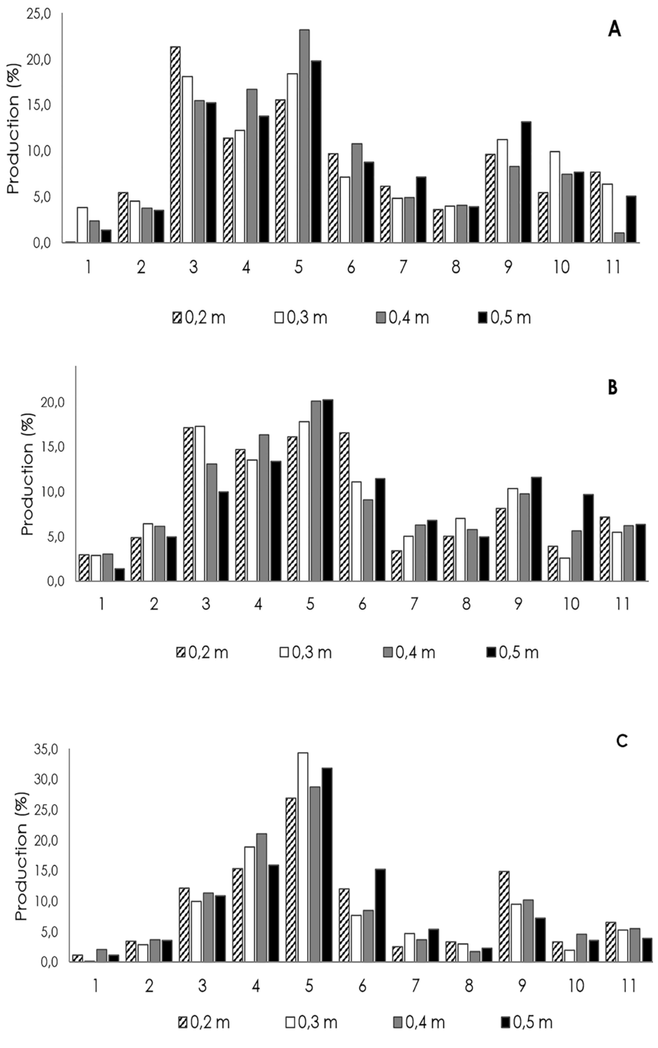

Figure 2. Distribution of Italian tomato production determined in the 11 harvests based on the training systems: Half-stake (A), open V (B) and cracking (C), with spacing (0.2, 0.3, 0.4, and 0.5 m) between plants.

knowledge of issues and production opportunities acts directly on the performance and viability of a business, which can improve its efficiency.

Tomato fruits may show reduced size, damage, or physiological disorders that may incur depreciation and be classified as non-commercial fruits (**Table 1**).

Reduced fruit size may be due to the low density, resource scarcity, or the characteristics of the hybrid used (Trento et al., 2021). Damage from physiological disorders is caused by many factors; black backgrounds are attributed to calcium deficiency, whereas an open locule is caused by boron deficiency.

The conduction system and spacing influence these characteristics, which may accentuate physiological disturbances or reduce fruit size.

These results demonstrate the magnitude of reduction in earnings for the producer and the main problems that occurred in the evaluated productive systems. Black backgrounds were seen in tutored treatment produce (apical rot, Table 1), requiring higher investments in soil correction, calcium application, fertilization, and management to satisfy plant requirements.

Staking maximizes tomato crop production, reducing weather attacks by pests and diseases via improving plant ventilation. The vertical stake system allows for better results compared to the cross method (Wamser et al., 2008).

Damage in undergrowth systems was mainly caused by pest attacks, affecting input expense (insecticides), quality, and food safety of the fruits, as harvests were performed weekly and improper applications could leave pesticide residues in the fruits.

Table 1. Non-commercial productivity; CP (t ha^{-1}), total percentage of fruit losses; losses, and percentage of type of fruit damage (black background: BB, pests: P, open locule: OL, zipper: Z, scalding: S and cracking: C) in Italian tomato production determined in different cropping systems

Spacing (m)	CP	Type of fruit damage (%)						
	(tha^{-1})	Losses	BB	P	OL	Z	S	C
				Half-stake				
0.2	20.9	11.7	45.5	23.8	7.6	2.8	16.1	4.2
0.3	9.8	7.9	50.3	22.9	11.8	1.7	11,2	2.0
0.4	10.2	8.3	29.3	27.0	17.9	3.7	20.8	1.5
0.5	11.1	11.6	39.5	32.1	12.4	0.8	11.4	3.8
				Open V				
0.2	15.2	9.9	42.6	33.4	5.5	0.9	12.2	5.3
0.3	14.4	12.6	36.9	45.5	7.0	1.9	8.1	0.6
0.4	13.2	13.3	27.3	46.3	12.5	1.1	9.8	2.9
0.5	15.4	15.1	24.4	47.9	13.4	0.4	10.5	3.5
				Cracking				
0.2	39.7	22.1	10.7	52.5	11.0	1.3	19.4	5.2
0.3	14.5	10.4	12.8	54.7	6.3	1.1	23.7	1.5
0.4	25.9	20.1	14.7	49.2	12.7	1.0	17.5	4.8
0.5	16.9	14.7	10.2	48.4	10.8	1.2	22.0	7.5

Cultivation in the Cracking system using mulching can be an alternative for tomato cultivation in the dry season, as it allows for cleaner fruits and increased production compared to creeping systems without coverage (Ogundare et al., 2015; Nair, 2018) and reduces the cost of labor and inputs (Angmo et al., 2018); however, increased soil and fruit moisture increases pest attack and fruit damage.

Therefore, tomato producers must perform a complex analysis of the factors that affect business success (Carvalho et al., 2014), via identifying positive and negative factors of the systems used for tomato production.

To calculate costs, all mechanized and manual operations (**Table 2**A), inputs (seeds, fertilizers, and pesticides; Table 2B), irrigation systems (Table 2C), and stacking systems (Table 2D) were measured for each cultivation system and spacing, to calculate EOC (EOC = A + B + C + D).

In mechanized operations, all the corresponding hours spent per hectare were measured, such as machine hours with the leveling harrow, enchanter, and furrower (value of R$ 100.00 per hm). Tracking systems allow for greater mechanization and lower manual operation costs, which facilitate and reduce operations, and optimize family labor.

Cultivation systems that reduce labor demand in tomato cultivation, such as those proposed in this study, which do not require labor for pruning or fruit thinning, contribute to reducing costs. In addition, the trailing system also eliminates the cost of fitting and conducting the plants, which is required in staking. Thus 23.5% the costs of labor are reduced in the trailing systems (**Table 3**).

Socoloski et al. (2017) evaluated three vegetable crops in Tangará da Serra, one of which was staked tomato, and obtained a production cost of BRL 81,791.10 per hectare, with BRL 50,00.00 spent on labor alone (representing 61.1%). This was a higher value compared to other studies, indicating that the reduction of labor and cultural practices can reduce production costs, thus providing profit.

Table tomato culture mainly utilizes family labor; however, reducing labor increase product competitiveness in the market and enable larger profits, in addition to increasing work and income in the field.

Regions with a labor shortages, such as the Nova Mutum municipality are limiting factors, as most of the population is involved in products and services aimed at commodity agriculture (soy, corn, and cotton); however, a demand for food production encourages this activity in these municipalities, in addition to changing systems with greater potential for mechanization and less labor input, thus allowing the emergence of enterprises aimed at the production of this species, mainly in production crawl systems.

In the comparison of cultivation systems (Table 2), open V registered a higher cost with inputs because it used double the material for staking the plants (wooden beams, bamboo, wires, and ratchets) compared to the half-stake system.

The opposite was observed in the creeper system, which had the lowest material use and input cost as it did not require staking or tillage. In several studies, input costs were most burdening on production, attributing to more than 46% of the total cost (Araújo & Araújo, 2008), similar to this study.

To calculate revenue, productivity was multiplied by the fruit commercial, considering R$ 1,500.00 (per ton) for all systems. Tomato fruits are marketed in bulk by kilograms of fresh products, regardless of their size, and only fruits with serious damage are discarded. Thus, the highest yield provided the highest revenue (Table 3).

In Mato Grosso, approximately 39% of the sold vegetables are sourced from other regions (Santos et al., 2017), increasing the product cost at retail and creating business opportunities for crop commercialization.

As for profits, tomato plants cultivated in the half-stake system with 0.2 m spacing, 0.2 m spacing, and low-growing system with 0.3 m spacing showed the highest profitability, exceeding 100,000 R$ (Table 3). Hence, the return on high yields is more valuable in comparison to the total cost with lower sale and production costs.

With a profit of R$ 135,281.00, the 0.2 m spacing and half-stake system was superior. It differed by R$ 125,686.00 from the 0.4 m spacing open V system, which obtained the lowest profit and could have resulted in a loss in the case of fruit devaluation. This result is mainly due to the lower production cost and high productivity provided via increase in plant population (33,333 plants ha^{-1}) in the half-stake system (Hachmann et al., 2014). Therefore, planting density is related to tomato production efficiency.

The second-highest profits were obtained via the 0.2 and 0.3 spacing creeping systems with profits of R$ 124,984.00 and R$ 108,995.00, respectively, exceeding R$ 100,000.00 in profit per hectare.

The results of evaluating innovative production systems from Almeida et al. showed the highest productivity and profitability in the Viçosa 20 systems and lower profitability in the crossbred systems. Population

Table 2. Economic analysis of the different management systems for tomato cultivation

Systems				Half stake				Open V				Creeping			
Plant spacing/ population	Items	Quantity/f hectare	Unit Value - R$	0.2	0.3	0.4	0.5	0.2	0.3	0.4	0.5	0.2	0.3	0.4	0.5
A-Op. Mec. and manuals															
Harrowing	hm	6.00	100	600	600	600	600	600	600	600	600	600	600	600	600
Millet green manure	hm	1.00	100	100	100	100	100	100	100	100	100	100	100	100	100
Enchanter	hm	6.00	100	600	600	600	600	600	600	600	600	600	600	600	600
Groove opening	hm	3.00	100	300	300	300	300	300	300	300	300	300	300	300	300
Furrow fertilization	dh	5.00	100	500	500	500	500	500	500	500	500	500	500	500	500
Transplant seedlings	dh	10.00	100	1	1	1	1	1	1	1	1	1	1	1	1
Fitillage	dh	30.00	100	3	3	3	3	500	500	500	500	-	-	-	-
Conducting Plants	dh	10.00	100	1	1	1	1	-	-	-	-	-	-	-	-
Fertilization Coverage	hh	22.00	15	330	330	330	330	330	330	330	330	330	330	330	330
Sprays	dh	15.00	50	750	750	750	750	750	750	750	750	750	750	750	750
Weeding	dh	5.00	100	500	500	500	500	500	500	500	500	-	-	-	-
Harvest	dh	80.00	100	8	8	8	8	8	8	8	8	8	8	8	8
Classification	dh	40.00	100	4	4	4	4	4	4	4	4	4	4	4	4
total op. Mec. and manuals				20,68	20,68	20,68	20,68	17,18	17,18	17,18	17,18	16,18	16,18	16,18	16,18
B - INPUTS															
Seed	Items.		0	10	6,667	5	4	10	6,667	5	4	10	6,667	5	4
seedling trays	Items.		29	7,526	5,017	3,763	3010	7,526	5,017	3,763	3010	7,526	5,017	3,763	3010
Substrate	kg		two	2,25	1,5	1,125	900	2,25	1,5	1,125	900	2,25	1,5	1,125	900
Organic Fertilizer	Ton.	5	350	1,75	1,75	1,75	1,75	1,75	1,75	1,75	1,75	1,75	1,75	1,75	1,75
Super simples Planting	kg	1,652	8	12,97	12,97	12,97	12,97	12,97	12,97	12,97	12,97	12,97	12,97	12,97	12,97
Urea planting	kg	67	7	456	456	456	456	456	456	456	456	456	456	456	456
Potassium chloride	kg	69	10	684	684	684	684	684	684	684	684	684	684	684	684
Ammonium sulfate	kg	700	7	4,69	4,69	4,69	4,69	4,69	4,69	4,69	4,69	4,69	4,69	4,69	4,69
Potassium nitrate	kg	1	9	9,28	9,28	9,28	9,28	9,28	9,28	9,28	9,28	9,28	9,28	9,28	9,28
Ca Nitrate	kg	7	3	22	22	22	22	22	22	22	22	22	22	22	22
Foliar Fertilizer	kg	3	55	179	179	179	179	179	179	179	179	179	179	179	179
Kocid®	kg	4	86	374	374	374	374	374	374	374	374	374	374	374	374
Amistar Top	L	1	360	235	235	235	235	235	235	235	235	235	235	235	235
Azimut®	L	1	132	98	98	98	98	98	98	98	98	98	98	98	98
Fipronil®	Items.	217	1	176	176	176	176	176	176	176	176	176	176	176	176
Benevia®	L	1	340	170	170	170	170	170	170	170	170	170	170	170	170
Premio®	kg	0	485	21	21	21	21	21	21	21	21	21	21	21	21
Pirate®	L	0	108	4	4	4	4	4	4	4	4	4	4	4	4
Decis®	kg	0	208	7	7	7	7	7	7	7	7	7	7	7	7
Azadiractina	L	43	65	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826
Total inputs				53,717	47,125	43,829	41,851	53,717	47,125	43,829	41,851	53,717	47,125	43,829	41,851
C - Irrigation															
Drip hoses	M	5,761	0.5	2,88	2,88	2,88	2,88	2,88	2,88	2,88	2,88	2,88	2,88	2,88	2,88
Pvc pipes	M	435	26	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6
Irrigation Accessories	Items.	22	25	543	543	543	543	543	543	543	543	543	543	543	543
Record	Items.	22	22	478	478	478	478	478	478	478	478	478	478	478	478
Total Irrigation				6,502	6,502	6,502	6,502	6,502	6,502	6,502	6,502	6,502	6,502	6,502	6,502
D - Tutoring															
Wooden beams	kg	783	11	8,89	8,89	8,89	8,89	17,781	17,781	17,781	17,781	-	-	-	-
Bamboo	Items.	2,391	two	4,783	4,783	4,783	4,783	9,565	9,565	9,565	9,565	-	-	-	-
Ribbon	kg	174	13	2,268	2,268	2,268	2,268	-	-	-	-	-	-	-	-
Ticket gate	Items.	261	3	783	783	783	783	1,565	1,565	1,565	1,565	-	-	-	-
Wire	kg	435	6	2,652	2,652	2,652	2,652	5,304	5,304	5,304	5,304	-	-	-	-
Screen siding	M	13,2	1	-	-	-	-	15,84	15,84	15,84	15,84	-	-	-	-
Mulch	M	6,6	1	-	-	-	-	-	-	-	-	6,666	6,666	6,666	6,666
Total staking				19,376	19,376	19,376	19,376	50,056	50,056	50,056	50,056	6,666	6,666	6,666	6,666
E - Effective operating cost (EOC) (A+B+C+D)				100,275	93,683	90,387	88,409	127,455	120,863	117,567	115,589	83,065	76,473	73,177	71,199
F - Other operating costs															
Interest on Invested capital	R$	50%/COE	6% a.	1504	1,405	1,356	1,326	1912	1813	1,764	1734	1,246	1,147	1,098	1,068
Administration	Hour	5	30	150	150	150	150	150	150	150	150	150	150	150	150
T. other cost op.				1,654	1,555	1,506	1,476	2,062	1963	1914	1884	1,396	1,297	1,248	1,218
G- Total op cost (TOC) (E+F)				101,929	95,238	91,892	89,885	129,517	122,826	119,48	117,473	84,461	77,77	74,425	72,417
H - Other fixed costs															
Cost of land	(BRL/ ha)	1.00	650	650.0	650.0	650.0	650.0	650.0	650.0	650.0	650.0	650.0	650.0	650.0	650.0

Table 3. Analysis of effective operating cost savings (EOC), total operating cost (TOC), total production cost (TLC), total production (Prod. T ha^{-1}), commercialization value (VC (R$/t), gross revenue (GR (R$/t), operating profit (OP R$), gross margin (GM (TOC)), profitability index (PI), production leveling point (PL (EOC/t)), and price leveling point (PP (EOC /R$/t)) of the different management systems for tomato cultivation

Indicators	Half-stake				Open V				Creeping			
	0,2	0,3	0,4	0,5	0,2	0,3	0,4	0,5	0,2	0,3	0,4	0,5
(EOC) R$	00.275	93.683	90.387	88.409	127.455	120.862,71	117.566,70	115.589,11	83.065,08	76.473,07	73.177,06	71.199,46
(TOC) R$	101.929	95.238	91.892	89.885	129.517	122.825,65	119.480,20	117.472,95	84.461,06	77.770,17	74.424,72	72.417,45
(TLC) R$	102.579	95.888	92.542	90.535	130.167	123.475,65	120.130,20	118.122,95	85.111,06	78.420,17	75.074,72	73.067,45
Prod. t ha^{-1}	158	114	114	86	139	100	86	87	140	125	103	98
VC (R$/t)	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500	1.500
(GR) R$/ha	237.210	170.295	170.625	128.685	208.695	150.540	129.075	130.710	209.445	186.765	154.365	147.660
OP R$	35.281	75.057	78.733	38.800	79.178	27.714	9.595	13.237	124.984	108.995	79.940	75.243
GM(TOC)%	132,7	78,8	85,7	43,2	61,1	22,6	8,0	11,3	148,0	140,1	107,4	103,9
(PI)%	57,0	44,1	46,1	30,2	37,9	18,4	7,4	10,1	59,7	58,4	51,8	51,0
(PL) (EOC)/ t	67	62	60	59	85	81	78	77	55	51	49	47
(PP) (EOC)/R$t	634	825	795	1.031	916	1.204	1.366	1.326	595	614	711	723

increase and the use of agronomic techniques contribute to productivity of tomato plants.

The highest gross margins (greater than 100%) were found in the trailing systems with spacings of 0.2 and 0.3 m, with values of 148.0 and 140.1%. The 0.2 m spacing half-stake system also showed a high revenue versus total cost, with a gross margin of 132.7% (Table 3). In tomato cultivation, producers idealize a margin above 100% as this enables safe payment of production costs for the subsequent harvest. Araújo and Araújo (2008) found a return of 144% on investment, which is economically satisfactory.

The lowest gross margins in this study were for the open V systems; their low productivity with high expenses, inputs, and labor make this system a financial risk to rural producers. Because 75% of its spacing had a margin below 22.6%, only the open V with 0.2 m spacing showed a value of 61.1%, below the ideal for safety of the activity.

The profitability index shows the profitability of the activity, the value as percentage of revenue after payment of all costs and charges (Martin et al., 1998); the evaluated systems showed percentages that varied from 11.2 to 59.9% (**Figure 3**). The highest profitability indices (above 50%) were observed in the low-growing systems (0.2, 0.3, 0.4 and 0.5 m spacing) and half-stakes with 0.2 m spacing.

These economic results show that, despite the high revenues obtained in this study, production cost affects business profitability. Therefore, several factors can affect the profitability of tomato cultivation that can be investigated via sensitivity analysis. Machado Neto et al. (2018) identified productivity and marketing price as the most important factors, including other highly relevant factors such as packaging and labor.

The leveling point of price and equilibrium production envisions the minimum production and minimum value received for the product necessary to pay all production costs. In both analyses, the lowest prices and leveling production were identified in the open V systems, which have require high productivity linked to high marketing prices. The leveling point (price) in spacings of 0.3, 0.4, and 0.5 m, was higher than R$ 1,200.00 per ton of tomatoes. This may increase the producer's insecurity, mainly in the experimental period, wherein a greater supply of tomatoes and reduce marketing costs.

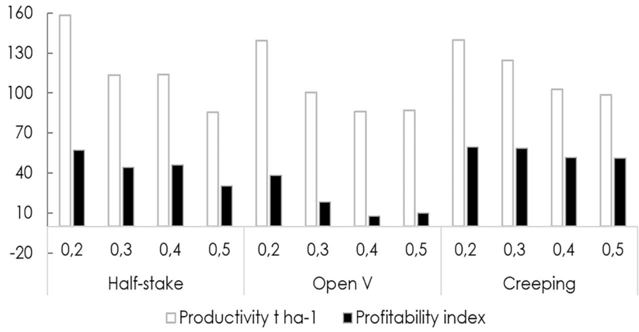

Figure 3. Profitability and productivity index of the evaluated productive systems.

The leveling points (price) of the creeping systems were below R$ 720.00 per ton of tomatoes produced, a satisfactory result owing to a safe and lower investment for the producer. Silva (2013) obtained a leveling point (price) of R$ 999.00 per ton, with the requirement of a margin of 51% and profit of 100%, and considered tomato production viable based on the return on investment. Thus, the lowest leveling points (price) were found in the creeping systems with 0.2 and 0.3 m spacing, and the half-stake systems with 0.2 m spacing, with values of R$ 595.00, BRL 614.00, and BRL 634.00 a ton, respectively.

The prices of commercial tomatoes increased in 2018, ranging from 30 to 95%, owing to climatic conditions, primarily the excessive precipitation in some regions, which directly affected supply and commercialization value (CONAB, 2018). Thus, reducing the cost of production and increasing profitability could be of interest, taking precautions in situations of low prices, particularly during the dry season.

Conclusion

The half-stake system with 0.2 m spacing and creeping systems with 0.2 and 0.3 m spacing present greater economic profitability for tomato cultivation, with greater productive efficiency and lower production costs. These cultivation systems are alternatives for tomato production *in natura*.

Acknowledgments

To the Research Support Foundation of the State of Mato Grosso-FAPEMAT for financing the project, process Nº.0588013/2016, Edital Nº 038 /2016 Induzido -FAPEMAT -Agricultura Familiar and to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-CAPES for the scholarship granted.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.