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Technical and Economic Evaluation of Three Types of Tomato Nutrient Solutions under Semi-Controlled Conditions

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Abstract

This study was conducted to evaluate the effect of three types of nutrient solutions on the development, performance, quality and cost of chonto tomato (*Solanum lycopersicum* L.) under semi-controlled conditions. The assessment was conducted in the farm Tesorito, Manizales, Colombia. An experimental design was established in randomized complete blocks (RCB), with 3 treatments, 4 replicates per treatment and 10 effective plants per replicate. The variables were: height of the first cluster, production per plant, yield t ha-1 and qualities of the fruit. The economic variables were production costs, cost-benefit ratio (C/BR), rate of return (IRR) and net present value (NPV). In general, production per plant was greater than 4.7 kg plant^{-1} and the average yield was 92 t ha^{-1}. The use of conventional fertilization (tt2) generated increased production of premium quality fruit with a value of 37.11 t ha^{-1}, demonstrating that conventional soil fertilization implemented in this culture under semi-controlled conditions in the company of drip irrigation system in the root zone improve outcomes of productive variables, increasing profitability and competitiveness with a net profit of USD$ $ 25203.68 ha^{-1}, with average selling price of USD$ 0.45 per kilogram and a unit production margin of USD$ 0.21 per kilogram, making this technology attractive and economically viable.

Keywords: tomato production, greenhouse, profitability, production costs

1. Introduction

Tomato demand continuously increases and encourages the different links in the production chain to its adoption, which represents one of the horticultural crops with the largest socio-economic impact worldwide (Testa et al., 2014). In Colombia, the surface of tomato production for 2013 was 16470 ha with 683538 harvested tons (FAOSTAT, 2015) and production under shelter has grown over the last decade, with the respective derivation of the need for more knowledge and research related to its production system (Jaramillo et al., 2007).

Tomato production is common in almost all areas of the country; however, it is concentrated mainly in the departments of Cundinamarca, Norte de Santander, Valle de Cauca, Boyacá, Huila, Antioquia, Risaralda and Caldas (Miranda et al., 2009). Tomato crops under shelter has grown spectacularly in Colombia, mainly in the municipality of Sutamarchán and the province of Ricaurte (Boyacá), where in recent years the area planted has increased up to 1009 ha under shelter.

According Perilla et al. (2007), tomato production in Colombia has been characterized in recent years by a good growth rate, as a result of improved commercial channels and the modernization of crops. Technological improvements of crops are represented in greenhouse production, implementation of strategies for integrated pest management, nutrition and use of good agricultural practices.

Thus, the need to optimize resources arises, in which plants are grown in a nutrient solution, with or without a substrate as a means of support. For tomato plants to grow without nutritional limiting nutrients, the nutrient solution should have a pH of 5.5 to 6.5, an electrical conductivity (EC) of 1.5 to 3.5 dS m^{-1} and ionic dissociated mineral nutrients in proportions and concentrations that avoid precipitates and antagonisms (Sanchez-Del Castillo et al., 2014). The plant modifies nutrient intake according to their stages of growth and development, climatic conditions (temperature, intensity and quality of light and relative humidity), fruit load, EC, dissolved oxygen in the nutrient solution, flow of the nutrient solution and pH (Sonneveld & Voogt, 2009). Thus, the proportions and concentrations of ions in the rhizosphere are changed, but EC increases which is corrected with a overwatering generating a drain of 10-40% (Lieth & Oki, 2008).

Fertilizers are increasingly expensive and represent a high percentage of the production cost in production systems with nutrient solutions (Huang, 2009). As part of the called sustainable agriculture, fertilization is conceived as the rational application of fertilizers while respecting the environment; in the process of fertilization, dosage of organic and mineral fertilizers should be done in such a way that they complement natural resources based on proper diagnosis of soil, plants, irrigation water and the use of new technologies for the split application of fertilizers (Vallejo, 1999).

The aim of this study was to evaluate the effect of three types of nutrient solutions applied by the irrigation system on the development, performance, quality and cost of chonto tomato (*Solanum lycopersicum* L.) under semi-controlled conditions in the Colombian Andes.

2. Materials and Methods

The study was conducted in Tesorito Farm of the University of Caldas, from May 2013 to January 2015, located in the city of Manizales, Department of Caldas (Colombia); with a height of 2340 m, annual average temperature of 17.5 ºC, relative humidity of 78%, annual rainfall of 2000 mm, sunshine per year of 1473 hours (Anuario Meteorológico Cafetero, 2013) and Andisol soils derived from volcanic ash with Sandy Loam texture rich in organic matter. The commercial hybrid of "torrano" tomato type chonto from the company Semillas Arroyave was used, which presents indeterminate growth, excellent vigor, resistance to nematodes and alternation and maturity of the first fruits of 70-75 d after transplanting (DAT) (http://www.semillasarroyave.com). Plantlets of 30 d old were used for transplantation, from plastic trays of 128 alveoli, using peat (*Sphagnum* enriched) as substrate.

The assessments were established under semi-controlled conditions with Agroclear® plastic shelter and the soil with Agromoulch X® plastic cover (black/black) in two greenhouses modules 12 m × 40 m (480 m^2) in "chapel gable" with a structure made of guadua, in a total area of 960 m^2. Planting distances used were 1.4 m between rows and 0.4 m between plants for a total of 19231 plants per hectare.

The treatments were:

1) Total soil fertigation. Implementation of all elements required by the crop (soil as substrate). The elements required by the plant were applied from the time of transplantation regardless of soil analysis; as conventionally, soluble sources were used with irrigation frequency of twice a week with different intensities, depending on the physiological stage (Table 1).

2) Conventional or soil fertilization every 20 days type farmer + application of water through the irrigation system. The mixture of minor granulated sources of N-P-K + required by the plant in each physiological state were used in the soil from the time of transplantation, starting with 25 grams per $plant^{-1}$, irrespective of soil analysis, considered conventional, increasing five grams per application every 20 days; the water required was used with a frequency of two weekly irrigations with different intensities depending on the physiological stage (Table 1).

3) Soil fertigation. Application of nutrients according to soil analysis and crop nutrient extraction. The elements required by the plant were applied from the time of transplantation considering soil analysis. Soluble sources were used; the frequency of irrigation was two per week with varying intensity depending on the physiological stage (Table 1).

The assessment corresponded to an experimental design in randomized complete blocks (RCB) with three treatments (Table 1), 4 replicates and 10 plants per replicate, within two greenhouse modules with chapel gable design of 480 m^2 (12 m × 40 m).

Table 1. Characteristics of soluble, simple and composite sources used in the preparation of the nutrient solution and grain fertilizer respectively in each phenological stage of the tomato crop for each treatment

Treatment	**Sources**	**Phenological stages**				
		1⁺	**2⁺⁺**	**3⁺⁺⁺**		
Total soil fertigation (tt1)	$CaNO_3$ (g)	641	962	1363		
	KNO_3 (g)	286	521	1053		
	$MgSO_4$ (g)	266	400	794		
	K_2SO_4 (g)	274	313	274		
	H_3PO_4 (cc)	110	158	224		
Conventional fertilization (tt2)	**Sources**	**Days after transplant (DAT)**				
		0	**20**	**40**	**60**	**80**
	10-20-20 (g)	10	10	10	10	10
	KCl (g)	10	10	10	15	20
	Borax (g)	5	5	0	0	0
	$MgSO_4$	0	0	10	10	10
Soil fertigation (tt3)	**Sources**	**Phenological stages**				
		1⁺	**2⁺⁺**	**3⁺⁺⁺**		
	KNO_3 (g)	517	620	1013		
	46-0-0	217	260	403		
	H_3PO_4 (cc)	106	127	180		
	$MgSO_4$ (g)	0	0	17		

Note. $^{+}$Transplant-start of flowering (0-30 days); ++ Flowering - fruit set; +++ Start of harvest.

A drip irrigation system was used in the study by means of drip tape, with a distance between drips of 30 cm and a flow rate by dropper of 30 cc min^{-1}. Two tanks with capacity of 2000 lt each were used, facilitating the preparation and distribution of nutrient solutions. With an efficiency of irrigation system 90%.

Drip irrigation was used with distance between droppers of 30 cm and average capacity by dropper of 30cc minute^{-1}, applying irrigation depth according to the phenological phases of the crop, beginning in the first weeks for each plant with 0.2 L day^{-1} and finishing with 1.5 L day^{-1}.

The density was 6.5 plants per m^2 and plastic fiber props with top sustained greenhouse structure were used. As the plant was growing, the prop thread was adjusted and the plant was de-suckered and defoliated. Cutting of the apical bud of the plants was made when these reached the height of the prop thread (2.5 m).

Harvest started 103 days after transplantation, removing the fruit from the peduncle and leaving the calyx. The harvest index used was the degree of fruit maturity of more than 90%. The collection was done twice a week for 80 days for a total of 20 passes in the production cycle.

The variables evaluated were height of the first cluster, total yield (kg), production per plant (g) number of fruits per unit area (sum of 17 cuts) and average fruit weight (g), quality (premium, first, second, < 60 g), and loss percentage.

For the analysis of production costs, a log of agronomic work was carried and efficiency was evaluated considering the time for each job to be executed. All values in the calculation of production cost were quoted in Manizales, Caldas, in the fourth quarter of 2015. Market prices in Manizales for 2015 were used as a reference for costing. The reference price for the calculation of the C/BR was performed with the average price per kg in the markets of the region in the last three years (2013, 2014 and 2015).

The concept of operational cost (Hoffmann et al., 1987) was used for the definition of production costs, which includes all production costs, without taking into account the interests of invested capital. Thus, it was possible to achieve production costs and cash flow on the basis of which the profitability of the crop were considered, guiding the product to the local market.

For the characterization of production costs, records were carried on a cost spreadsheet adopted from the model by the Corporación Colombia Internacional-CCI [International Colombia Corporation] (Sistema de Información de Precios del Sector Agropecuarios-SIPSA, 2012/Agricultural Sector Price Information System). All values were calculated in US dollars per hectare (USD \$ ha^{-1}) with the exchange rate reported in the fourth quarter of 2014 according to the Bank of the Republic of Colombia.

The same technological level was considered in the estimates of production costs, maintaining the proportionality of hours spent with manual labor and the quantity of inputs. Technical coefficients (man-day hours and the number of inputs) were based with workers efficiencies in Tesorito Farm. The costs are divided into two parts as follows:

Manual operations: the average value of USD \$10.71 per day of service (man-day) was considered, equivalent to the remuneration paid to rural workers in the region, not including contributions to social security since, in general, the activity is carried out by family manpower or hired labor in specific seasons.

Inputs: the average price among major distributors in the region was used.

Cash flow of the investment: after defining production costs (Table 1), the cash flow was estimated considering an investment of eight months. Values are expressed in US dollars per hectare at the time of the investment. CPI (consumer price increase) of 2.94% from January 2013 to January 2015 was used for calculating the adjustment to the value of some inputs; FTD values, inflation and uptake values from the Bank of the Republic in 2015 were taken into account for calculating NPV and IRR.

Gross income, net income, production costs and economic indicators for each introduction such as the production unit margin, cost benefit ratio, rate of return (PUM, C/BR and IRR) were calculated to analyze the profitability of the crop.

The data obtained were evaluated by analysis of variance using SAS statistical software (SAS Inst. Inc. Cary, NC); further, comparative average tests were conducted by Duncan's test at significance level of 5%. Normal test was performed by Shapiro Wilks.

3. Results and Discussion

Production costs for one hectare for each of the treatments were similar up to the beginning of fertilization, this because both cultural practices and inputs used have similar costs. The main variation was in the category fertilizers, specifically associated with fertilizer costs (Table 2). To estimate calculations of total costs per hectare were taken into account: cost of labor, greenhouse amortization cost for a total of six lifecycles; also it was taken into account the amortization cost for the structure for irrigation and inputs.

Table 2. Economic analysis of three nutrient solutions of chonto tomato under semi-controlled conditions in Manizales, Caldas

Teatment	Production costs (USD\$ ha)	Rto (K ha)	Sale price (USD\$ Kg)				Gross income (USD\$ Kg)	Net income (USD\$ Kg)	C/BR	NPV USD\$	IRR %
			Premium \$0.379	First \$0.275	Second \$0.088	< 60 g \$0.05					
Total soil fertigation (tt1)	\$31790.36	85820	32600	23680	7580	4300	\$51388.18	\$19597.82	1.6	\$17521.78	62
Conventional fertilization (tt2)	\$29858.47	94670	37110	20910	9440	5800	\$55062.15	\$25203.68	1.85	\$22979.21	84
Soil fertigation (tt3)	\$30158.21	95450	36340	18820	9730	6100	\$53202.69	\$23044.48	1.75	\$20895.14	70

The highest production cost is the total soil fertigation treatment (tt1) with USD \$ 31790.35 ha^{-1}; the share of the costs of fertilizers was 14.79% higher than the other two treatments evaluated, due to the elements required by the plant being applied from the time of transplantation regardless nutritional balance calculated with soil analysis conventionally (Table 2), followed by soil fertigation treatment (tt3) and conventional fertilization (tt2) with shares of 10.18% and 8.53% of total costs respectively (Table 2). For each of the treatments, share rates in labor were similar with 19.90%, 21.93% and 20.97% respectively, mainly due to obtaining equal yields with 85820 kg ha^{-1}, 94670 kg ha^{-1} and 95450 kg ha^{-1} respectively (Table 3). Testa et al. (2014) obtained an average production cost of USD \$ 229.570 for cherry tomato grown in 30 greenhouses.

Table 3. Test of averages (Duncan) in evaluating performance components of three nutrient solutions of chonto tomato under semi-controlled conditions in Manizales, Caldas

Treatment	Height 1st cluster (cm)	Rto (ton ha^{-1})	Pxn plant^{-1} (g)	Premium (ton)	First (ton)	Second (ton)	60 g (ton)	Loss (ton)
Total soil fertigation (tt1)	50.3a	85.8ab	4280a	37.11a	23.68a	7.68b	4.3b	17.6b
Conventional fertilization (tt2)	47.8ab	94.7a	4913a	32.6ab	20.91ab	9.44a	5.8a	21.3ab
Soil fertigation (tt3)	46.9ab	95.5a	4996a	36.34ab	18.82b	9.73a	6.1a	24.4a

Note. * Values followed by different letters differ significantly ($P < 0.05$) according to Duncan's test.

The category with the largest share in production costs for all treatments evaluated were the general inputs such as seeds, plastic mulch, agrochemicals, fertilizers and amendments, which ranged between 39.91% and 42.49% of total production costs.

Amortization costs per cycle of 8 months of greenhouse varied between 8.01% and 8.12% of total costs, ranking fourth in terms of costs. Meanwhile, higher production costs in these materials is due to the high demand for labor for the work of propping and harvesting mainly (Table 4).

Table 4. Structure of production costs in Colombian pesos per hectare of three nutrient solutions of chonto tomato under semi-controlled conditions in Manizales, Caldas

Concept	Unit	Quantity	Quantity (ha)	R/V Unit (USD$)	R/V Total (USD$)	R/V ha (USD$)
FARM INPUTS						
Seeds	gr	2.06	85.80	$26.42	$54.42	$2,267.55
Trays	unit	4.50	187.50	$2.47	$11.10	$462.63
Peat	kg	2.25	93.80	$1.28	$2.87	$119.53
Poultry manure	kg	25.00	1041.70	$0.10	$2.42	$100.94
Rice husks	kg	1.25	52.10	$0.05	$0.07	$2.74
Treacle	kg	0.30	12.50	$0.41	$0.12	$5.10
Plastic mulch black	kg	4.00	166.70	$3.78	$15.12	$630.02
Hooks + wire-10	kg	4.80	200.00	$2.05	$9.82	$409.09
Extra perforated basket	unit	10.00	416.70	$7.60	$75.99	$3,166.25
FERTILIZERS AND AMENDMENTS						
Aglime	kg	37.30	1554.20	$0.09	$3.37	$140.29
Cosmocel	kg	0.02	1.00	$8.34	$0.20	$8.34
Fosfacel	kg	0.004	0.20	$8.56	$0.03	$1.43
Terrasorb 4 radicular	lt	0.06	2.50	$12.79	$0.77	$31.97
Polical	lt	0.05	2.00	$7.40	$0.35	$14.48
Agro-k	kg	0.23	9.40	$10.51	$2.36	$98.49
INSECTICIDES AND FUNGICIDES						
Furadan	lt	0.01	0.50	$17.88	$0.22	$9.31
Bactón	lt	0.04	1.70	$2.32	$0.93	$38.67
Actara	lt	0.01	0.20	$244.29	$1.22	$50.89
Sistemin	lt	0.03	1.30	$17.02	$0.51	$21.27
Evisect	kg	0.07	2.90	$96.90	$6.78	$282.63
Karate	lt	0.03	1.10	$55.07	$1.49	$61.95
Thrichoderma	kg	0.08	3.30	$13.21	$1.06	$44.03
Mancozeb	kg	15.00	625.00	$7.27	$109.01	$4,542.19
Rhodax	kg	0.08	3.30	$19.25	$1.54	$64.16
Elosal	kg	0.05	2.10	$8.20	$0.41	$17.09
Agrodyne	kg	0.01	0.30	$19.64	$0.12	$4.91

ADJUVANTS AND REGULATORS						
Inex-a	kg	0.13	5.40	$15.59	$2.03	$84.43
Cosmoaguas	lt	0.01	0.20	$10.71	$0.05	$2.23
Cosmoil	lt	0.03	1.30	$3.72	$0.11	$4.65
TOTAL					$304.50	$12,687.26
GREENHOUSE INPUTS						
Guadua de 4.5 m	Unit	20.00	416.69	$1.57	$31.50	$656.24
Guadua de 7.5 m	Unit	10.00	208.31	$2.10	$21.00	$437.49
Guadua de 6.5 m	Unit	20.00	416.66	$1.84	$36.75	$765.62
Guadua de 3.0 m	Unit	16.00	333.27	$1.31	$21.00	$437.49
Tensioners ½	Unit	10.00	208.33	$2.73	$27.30	$568.74
Screws Threaded rod	m	5.00	104.17	$2.41	$12.07	$251.56
Nut	Unit	80.00	1660.32	$0.03	$2.52	$52.50
Packing ring	Unit	80.00	1660.32	$0.03	$2.52	$52.50
Wire Cal. 10	Kg	25.00	520.79	$2.05	$51.19	$1,066.39
Wire Cal. 12	Kg	18.00	375.00	$2.09	$37.61	$783.55
Industrial sewing machine	Unit	1.00	20.83	$51.45	$51.45	$1,071.86
Nails de 2.5"	Kg	1.00	20.83	$2.10	$2.10	$43.75
Nails de 1.0"	Kg	1.00	20.83	$2.10	$2.10	$43.75
Plastic	Kg	100.00	2083.31	$4.46	$446.24	$9,296.77
TOTAL COSTS					$745.35	$15,528.23
AMORTIZATION CYCLES		6			$124.23	$2,588.04
IRRIGATION INPUTS						
Hose 2"	m	70.00	1458.33	$1.32	$92.61	$1,929.35
Hose 2" connector	m	100.00	2083.33	$0.93	$92.61	$1,929.35
Tank 2000 Liters	Unit	2.00	41.67	$199.50	$399.00	$8,312.40
Drippping line	m	400.00	8333.33	$0.14	$55.65	$1,159.36
Motor pump 0.75 HP	Unit	1.00	20.83	$420.00	$420.00	$8,749.90
Motor pump starter	Unit	1.00	20.83	$367.50	$367.50	$7,656.16
Motor pump accessories	Unit	1.00	20.83	$52.50	$52.50	$1,093.74
Registers	Unit	4.00	83.33	$25.20	$100.80	$2,099.98
TOTAL COSTS					$1.580.65	$32,930.25
AMORTIZATION CYCLES		6			$263.44	$5,488.37
SOIL FERTIGATION INPUTS (TT1)						
KNO3	Kg	18.18	920.15	$2.22	$40.34	$2,041.36
K2SO4	Kg	6.34	320.85	$1.66	$10.54	$533.45
MgSO4	Kg	13.79	697.78	$0.74	$10.27	$519.57
CaNO3	Kg	26.06	1318.64	$0.84	$21.93	$1,109.63
H3PO4	lt	4.29	216.91	$2.30	$9.84	$497.80
TOTAL FERTILIZATION					$92.91	$4,701.81
CONVENTIONAL FERTILIZATION (TT2)						
10-20-20	Kg	19.00	961.55	$0.85	$16.10	$815.03
MgSO4	Kg	11.40	576.93	$0.74	$8.49	$429.58
KCL	Kg	24.70	1250.02	$0.75	$18.52	$937.14
BORAX Technical	Kg	3.80	192.31	$1.60	$6.07	$306.98
H3PO4	lt	0.50	25.30	$2.30	$1.15	$58.07
TOTAL FERTILIZATION					$50.32	$2,546.80
SOIL FERTIGATION INPUTS (TT3)						
KNO3	Kg	18.53	937.71	$2.22	$41.11	$2,080.32
46-0-0	Kg	7.50	379.51	$0.48	$3.63	$183.68

MgSO4	Kg	0.22	11.18	$0.74	$0.16	$8.33
H3PO4	lt	3.44	174.09	$2.30	$7.89	$399.54
Soil analysis	Unit	1.00	10.00	$39.78	$39.78	$397.80
TOTAL FERTILIZATION					$92.58	$3,069.66
MANPOWER IRRIGATION SETUP						
Holes 80	Wage	1.00	20.83	$10.71	$10.71	$223.13
Structure erection	Wage	5.00	104.17	$10.71	$53.55	$1,115.63
Rafters	Wage	5.00	104.17	$10.71	$53.55	$1,115.63
Templetes	Wage	1.00	20.83	$10.71	$10.71	$223.13
Plastic templing	Wage	1.00	20.83	$10.71	$10.71	$223.13
Plinth	Wage	1.00	20.83	$10.71	$10.71	$223.13
Stacking	Wage	5.00	104.17	$10.71	$53.55	$1,115.63
Irrigation Setup	Wage	5.00	104.17	$10.71	$53.55	$1,115.63
Cost Manpower					$257.04	$5,355.00
Amortization cycles		6			$42.84	$892.50
MANPOWER SETUP (TT2)						
SEEDBED						
Seedbeds	Wage	0.25	10.40	$10.71	$2.68	$111.56
Immersion	Wage	0.25	10.40	$10.71	$2.68	$111.56
Irrigation	Wage	0.38	15.60	$10.71	$4.02	$167.34
TERRAIN SETUP						
Row setup	Wage	0.50	20.80	$10.71	$5.36	$223.13
Calcimine	Wage	0.25	10.40	$10.71	$2.68	$111.56
Poultry manure incorporation	Wage	0.25	10.40	$10.71	$2.68	$111.56
Revision irrigation lines	Wage	0.13	5.20	$10.71	$1.34	$55.78
Phosphoric acid application	Wage	0.04	1.70	$10.71	$0.44	$18.41
Mulch setup	Wage	0.29	12.10	$10.71	$3.12	$129.97
Fertilization 30gr/pl.	Wage	0.08	3.40	$10.71	$0.88	$36.82
PLANTING						
Soil hydration	Wage	0.21	8.60	$10.71	$2.22	$92.60
Transplant	Wage	0.02	0.90	$10.71	$0.22	$9.32
Replanting	Wage	0.06	2.60	$10.71	$0.67	$27.89
Application of toxic sebum	Wage	0.13	5.20	$10.71	$1.34	$55.78
GENERAL WORK						
Application	Wage	2.36	98.30	$10.71	$25.28	$1,053.15
Fertilization 30gr/pl (1ra dose)	Wage	0.13	5.20	$10.71	$1.34	$55.78
Fertilization 30gr/pl (2da dose)	Wage	0.13	5.20	$10.71	$1.34	$55.78
Fertilization 35gr/pl (3da dose)	Wage	0.19	7.80	$10.71	$2.01	$83.67
Fertilization 40gr/pl (4ta dose)	Wage	0.19	7.80	$10.71	$2.01	$83.67
Stacking	Wage	0.38	15.60	$10.71	$4.02	$167.34
De-suckering	Wage	1.15	47.70	$10.71	$12.26	$510.96
Prop Adjusment	Wage	0.40	16.50	$10.71	$4.23	$176.27
Pruning + sanitary	Wage	0.69	28.60	$10.71	$7.36	$306.80
HARVEST AND POST-HARVEST						
Harvest	Wage	1.88	78.30	$10.71	$20.13	$838.95
Calssification	Wage	2.00	83.30	$10.71	$21.42	$892.50
Eradication	Wage	0.38	15.60	$10.71	$4.02	$167.34
TOTAL WAGES		12.67	528.10			
COST MANPOWER					$135.73	$5655.49

MANPOWER SETUP (TT1 and 3)						
SEEDBED						
Seedbeds	Wage	0.25	10.40	$10.71	$2.68	$111.56
Immersion	Wage	0.25	10.40	$10.71	$2.68	$111.56
Irrigation	Wage	0.25	10.40	$10.71	$2.68	$111.56
TERRAIN SETUP						
Row setup	Wage	0.50	20.80	$10.71	$5.36	$223.13
Calcimine	Wage	0.25	10.40	$10.71	$2.68	$111.56
Poultry manure incorporation	Wage	0.25	10.40	$10.71	$2.68	$111.56
Revision irrigation lines	Wage	0.13	5.20	$10.71	$1.34	$55.78
Phosphoric acid application	Wage	0.04	1.70	$10.71	$0.44	$18.41
Mulch setup	Wage	0.29	12.10	$10.71	$3.12	$129.97
Fertilization 30gr/pl.	Wage	0.08	3.40	$10.71	$0.88	$36.82
PLANTING						
Soil hydration	Wage	0.21	8.60	$10.71	$2.22	$92.60
Transplant	Wage	0.02	0.90	$10.71	$0.22	$9.32
Replanting	Wage	0.06	2.60	$10.71	$0.67	$27.89
Application of toxic sebum	Wage	0.13	5.20	$10.71	$1.34	$55.78
GENERAL WORK						
Application	Wage	2.36	98.30	$10.71	$25.28	$1,053.15
Nutrient solution (1st stage)	Wage	0.06	2.60	$10.71	$0.67	$27.89
Nutrient solution (2nd stage)	Wage	0.06	2.60	$10.71	$0.67	$27.89
Nutrient solution (3rd stage)	Wage	0.13	5.20	$10.71	$1.34	$55.78
Stacking	Wage	0.38	15.60	$10.71	$4.02	$167.34
De-suckering	Wage	1.15	47.70	$10.71	$12.26	$510.96
Prop Adjusment	Wage	0.40	16.50	$10.71	$7.36	$306.80
Pruning + sanitary	Wage	0.69	28.60	$10.71	$7.36	$306.80
HARVEST AND POST-HARVEST						
Harvest	Wage	1.88	78.30	$10.71	$20.13	$8,389.50
Classification	Wage	2.00	83.30	$10.71	$21.42	$892.50
Eradication	Wage	0.38	15.60	$10.71	$4.02	$167.34
TOTAL WAGES		12.17	507.20			
COST MANPOWER					$130.38	$5432.37

Concept	Total soil fertigation (tt 1)		Conventional fertilization (tt 2)		Soil fertigation (tt 3)	
	R/V (USD$)	**% part**	**R/V (USD$)**	**% part**	**R/V (USD$)**	**% part**
Production costs	$31790.36	100.00	$29858.47	100.00	$30158.21	100.00
General inputs costs	$12687.26	39.91	$12687.26	42.49	$12687.26	42.07
Costs inputs greenhouse setup	$2588.04	8.14	$2588.04	8.67	$2588.04	8.58
Costs inputs irrigation system	$5488.37	17.26	$5488.37	18.38	$5488.37	18.20
Costs Manpower + setup	$6324.87	19.90	$6547.99	21.93	$6324.87	20.97
Costs Fertilizers	$4701.81	14.79	$2546.80	8.53	$3069.66	10.18

In a study by Perilla et al. (2011), with the aim of characterizing the social, technical and economic conditions of the production system of tomato in greenhouse in the municipalities of Guateque, Sutatenza and Tenza in the department of Boyacá (Colombia), they emphasize that the total cost of labor for crop maintenance reaches USD \$13821 ha^{-1}; for our study, maintenance reached values of USD \$29187.3 ha^{-1}. These same authors highlight harvest as the operation of the production process which involves higher cost, since this is done twice a week and a considerable amount of labor is used in it, similar to that developed in this study, amounting to USD \$11182 ha^{-1}. Following this in terms of cost are maintenance pruning, which is done weekly and takes on average three to four days of labor. Similar results were obtained by Testa et al. (2014), evaluating cherry tomato production in 30 greenhouses in Italy.

No significant differences were observed form the evaluation of yield components ($P < 0.05$) according to Table 2. For the behavior of the variable performance, soil fertigation treatment (tt3) stands out with 95.5 t ha^{-1}, followed by conventional fertilization with 94.7 t ha^{-1}. Meanwhile, the total soil fertigation treatment (tt1) showed a mean behavior with value of 85.8 t ha^{-1} (Table 3).

For the variable premium fruit quality, total soil fertigation (tt1) and soil fertigation (tt2) stand out with 37,11 t ha^{-1} and 36.34 t ha^{-1} respectively. The behavior was opposite to the conventional fertilization treatment (tt2), with lower values of 32.6 t ha^{-1}. Similar behavior was for the first and second qualities. As for losses, soil fertigation treatment (tt3) presented the highest values of losses with 24.4 t ha^{-1} (Table 3).

For fruit losses, two factors influenced in the production system as were the physiopathy known as fruit zipper and damage caused by the tomato moth (*Tuta absoluta* Meyrick), increasing the losses in production peaks. According to Dannehl et al. (2012), climatic conditions under greenhouse conditions significantly promote the accumulation of lycopene by 46%, carotene by 35%, phenolic compounds by 16% compared to tomato plants grown in conventional manner to free exposure, increasing yields and qualities of the fruit and the health of the fruit.

Preciado et al. (2011) evaluated different organic nutrient solutions in greenhouse tomato production, obtaining the highest yield of fruit by using fertilization with inorganic nutrient solution, followed by fertilization with vermicompost tea. The plants fertilized with vermicompost leachate produced the least amount of fruits of all treatments (42% compared to the Steiner nutrient solution). Thus, organic nutrient solutions can represent an environmentally friendly alternative compared to conventional nutrient solutions in the greenhouse production of tomatoes.

3.1 Economic Viability of the Investment

The conventional fertilization treatment (tt2) gave the best net income with USD \$25203.67 ha^{-1}, reflecting a high potential, followed by soil fertigation treatment (tt3) with USD \$23044.48 (Table 2). Evaluating two tomato planting systems under controlled conditions, Perilla et al. (2011) obtained a net income of USD \$15151.32 for the model of planting in soil, surpassing the net income of the seeding-in-bag system USD \$5485.23, attributing this difference to productivity per m^2 in each system (higher population density). Testa et al. (2014), showed a net income of USD \$2523.29, a figure that highlights the modest income for farmers in the conditions of Sicily (Italy). According to the same authors, this is due to structural and commercial problems of cherry tomato farms under controlled conditions that adversely affect their export potential and competitiveness; in addition, the small size of farms and their production process limit a higher degree of mechanization in farming operations, with a negative impact on the price of production, also hindering the introduction of technological innovations. Consequently, the marketing of tomato is practically limited to local and regional markets, as it happens in other production areas.

According to the cost benefit ratio thrown by the analysis adopted (Table 2), the treatment with conventional fertilization (tt2) is the one with higher returns, followed by the soil fertigation treatment (tt3), standing out as financially attractive opportunities for an investor in this type of production system. In assessing the efficiency of the investment (RR), the treatments with conventional fertilization (tt2) and soil fertigation (tt3) showed an efficiency of 84% and 70% respectively, closely to the cost benefit ratio obtained. Perilla et al. (2011), obtained a C/BR between 1.36 and 1.14 economically evaluating greenhouse tomato crops in two categories – in soil and in bag-, constituting a profitable operation, since they exceed by far the money return ratio (opportunity cost) offered by the financial system through the interest rate of opportunity, expressed in the FTD benchmark at 90 days (fixed time deposit). Thus, the economic analysis shows the fragility of the economic sustainability of the system, due to the change in prices of the product and in regard to the impact of unpredictable increases in input costs.

The treatments evaluated showed positive results in revenue generation comparing these investments to other interests of opportunity, as is demonstrated by calculating the VPB at an interest rate of 6.20% E.A. and inflation of 2% for 2009 (Table 2). Gains of USD \$17521.78 were estimated for the total soil fertigation treatment (tt1). Conventional fertilization (tt2) and soil fertigation (tt3) had higher earnings of USD \$22979.21 and \$20,895.14 respectively, this hypothesis is supported by the IRR, which exceeds the value of interest of opportunity in the three treatments, indicators that determine that the project complies with the basic objective of the producer which is to maximize investment; it also shows economically that treatment 2 generates the best results.

4. Conclusions

The conventional soil fertilization implemented in this culture under semi-controlled conditions in the company of a dripping irrigation system in the root zone improves the outcome of productive variables, increasing profitability and competitiveness. The indiscriminate use of fertilizers without interacting with soil analysis and crop nutrition as in the total soil fertigation does not increase in production, quality or performance of crop.

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