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Total Growth of Tomato Hybrids Under Greenhouse Conditions

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1. Introduction

Often in intensive production of tomato, the fertilization is applied by the farmers without consider the suitable doses in order to cover nutritional requirements according to crop physiological stages. Thus, appropriate crop management is a strategic demand to maintain or increase tomato production. In spite of many researchers conducted experiments in this subject and data is available about physiological stage requirements for plant nutrition, only few studies have been focused to nutritional parameters. The crop growth curves and nutrient uptake for tomato may determine uptake rate for a particular nutrient eluding possible deficiencies and superfluous fertilizer consumption. The daily rates of nutrient uptake are depending on crop and wheater (Scaife and Bar-Yosef, 1995; Honorato *et al.*, 1993; Magnificent *et al.*, 1979; Miller *et al.*, 1979); however, crop requirements and opportune fertilizer applications, are little known in many of fresh consumption crops. In Mexico, vegetable production is located at desert areas in the north and middle of the country where water shortages have constraints with impact on of water demands the crops of tomato, pepper and cucumber. Thus, the surface for crop production in greenhouses has increased from 350 ha in 1997 (Steta, 1999) to about 5000 ha in 2006 (Fonseca, 2006), because the increasing demand for quality products and the risk of losses on field for crop production.

Imas (1999) found that nutrient uptake and fertilization recommendations are conditions depending of crops. For example, tomato crops under hydroponic greenhouse environments have averaged 200 t ha⁻¹ which is significantly higher than the 60-80 t ha⁻¹ yield, typically observed in an open field. In contrast to tomato crops grown in an open field, nutrient uptake in greenhouse environment can be duplicated or triplicated. In practical terms, crop growth cycle is divided according to physiological stages thence different concentrations or amounts of nutrients have to be applied according to recommendations given by Department of Agriculture. In the tomato production are considered four physiological stages: establishment-flowering, flowering-fruit set, ripening of tomato fruit (the first-crop harvest and last harvest on the crop). In each stage concentrations of nitrogen (N) and phosphorus (K) are increasing while nitrogen-phosphorous are decreasing because potassium is uptaken in large quantities during the reproductive stage of the crop (Zaidan

and Avidan, 1997). In order to determine nutrient uptake more accurately, crop growth can be scheduled by chronological periods of sampling and analysis nearest one another.

The nutrient demand is the maximum amount of nutrient that a crop needs in order to meet their metabolic growth demand and development and that is calculated to maximize production goals and domestic demand price (nutritional optimal concentration of total biomass (air and / or root) at harvest time); however this criteria is not yet thought by the farmers. An appropriate method for such calculation is to use mass balance concept in a hydroponic system. In this way, nutrimental control is more efficient in the nutritive solution and its effect can be seen rapidly in the plants (Steiner, 1961). The method before mentioned is based on the composition of plant dry matter which consists of 16 essential nutrients; however, only thirteen are directly uptaken by plants from soil. Therefore, if the amount of total dry matter production (root + aerial part) during the cycle of growth and development as well as nutrimental concentration in each physiological stage is determined, the amount of nutrients that the plant absorbs can be estimated. With this analysis it is possible to establish a program of daily/weekly fertilization for crop production. This would result in a substantial economic savings on fertilizer costs and also in a decrease of negative environmental impact for its inappropriate applications.

2. Tomato hybrids analysis

The field study was conducted on the farm “El Cuento” located in the town of Marín, Nuevo León, Mexico (latitude N 25° 53' and longitude W 100° 02' and 400 m above sea level), where two greenhouses were used (Figure.1), first one of these greenhouses was a tunnel type of 900 m² (75 m x 12 m and 7 m high) and second one was multi-Korean tunnel type of 1300 m² (45 m x 30 m). It was used an open hydroponics system during the tests of two indeterminate hybrid tomatoes beef type.

The seeds were sown in a mixture of peat moss and perlite (1:1 v/v) in containers of 200 cavities. The transplanting was realized at 40 days after sowing. Plants were transplanted inside of 2 gallons polythene bags (white outer and black inner, Fig.2) with a mixture of perlite and peat moss (1:1, v/v). In the Korean type greenhouse it was settled 50% of plants of the hybrids Cayman (1700) and Charleston (1700). In the tunnel type greenhouse it was established 2220 plants of the hybrid Charleston, in both cases it was used a density of 2.5 plants m⁻². The hydroponic irrigation system and nutrition of the plants were conducted with emitters calibrated to 4 min L⁻¹. It was drained of 10 to 15% of the hydroponic solution applied. The nutrimental solution used was suggested by Rodríguez *et al.* (2006).

Plant sampling and were conducted according to tomato crops and greenhouse type (Fig 3). On plant sampling, three plants, visually uniform, were removed from the hydroponic system (substrate) every 15 days after plant plantation total dry matter was determined considering root + leaves + stems + flowers and fruits (if they were in the plant) To obtain the biomass model in both production and the nutrient uptake, roots, stems, leaves, and fruits were included. The samples were analyzed in the Laboratory of Soil, Water and Plant Analysis at the Agronomy School of Autonomous University of Nuevo Leon, where plant specimens were washed with deionizer water to obtain their dried weights. In addition to this parameter, dry matter, nitrogen, phosphorus, potassium, calcium and magnesium were determined per plant sample.



Fig. 1. Tunnel-type greenhouse used for experimentation located in Marín, Nuevo León, Mexico.



Fig. 2. Vinyl bag used for growing tomato in a hydroponics system.



Fig. 3. Tomato plants inside of the experimental greenhouse.

To determine the dry weight at constant weight, samples were milled and then placed in a forced convection oven (Riossa model F-62, Mexico) at 70° to 80°C. Samples were screened through a 50 μ m mesh. Determination of total nitrogen was done by the Kjeldhal method (Rodríguez and Rodríguez, 2011). A wet digestion microwave (MAR SX, EMC Corporation, North Carolina, USA) was used in order to analyze P, K, Ca, and Mg. Three dried samples of 0.5 ± 0.001 g were placed in a digestion flask (Teflon PFA vessels of a capacity of 120 mL) and then 5 mL of HNO_3 were added. The instrument was programmed with a ramp of 15 min to reach a temperature of 180 degrees Celsius and a pressure of 300 PSI and keeping these conditions for 5 minutes. Finally, to the samples were left to cool for 15 minutes.

The dry matter accumulated values in the hybrid tomato were analyzed with the DM Sigma Plot 10.0 Program and Microsoft Excel Office 2003 software and it was found that the best fitted linear regression model. To calculate the equations were considered the average values of both hybrids.

3. Flowering period

The flowering period occurred after 20 days after plant plantation, fruits set showed up 10 days later and until 55 days after transplanting. During the beginning of flowering there was a low accumulation of dry matter. On the fruit set and harvest time of fruit an

accumulation of intense biomass was observed (Figures. 4 and 5) until the establishment of the harvest. In last stage of crop growth the dry matter is decreasing as well as the nutrient uptake. Bugarin *et al.* (2002), coincided in their research due in same crop growth stage any nutritional deficit decreases production.



Fig. 4. Tomato plants (variety Charleston) in breaking stage.

4. Accumulation of dry matter production

Accumulation of dry matter production had a linear behavior up to 96-day initial crop period. Thereafter, an erratic behavior was observed probably as a consequence of the conditions of high temperatures and low relative humidity occurred in those greenhouse designs. This condition caused a severe reduction in dry matter accumulation, low pollination of fruit and fruit set. Sampling finished after 170 days since transplanting stage; however, plant health recovery did not occurred, reducing drastically fruit production to about one third of the best period, from 2.5 to 0.8 kg m² after 125 days since transplanting. The same reduction is normal but it occurs gradually as the harvest progresses and the number of clusters.

Observed data sets were analyzed for dry matter production during 96 days after transplanting. Three models of linear fitting (Table 1 and Figures 6, 7, 8) with R² values of 0.96, 0.99 and 0.91 for hybrids: Cayman (CAI), Charleston greenhouse Korean (CHK) and Charleston in greenhouse Tunnel (CHT), respectively, were obtained. The R² value for the average of both hybrids was 0.96 (Table 1, Figs. 6 and 7) to predict possible accumulation of DM with the models obtained for each hybrid, is to believe the 170 days scheduled time to remove crop residues and begin the next crop season.



Fig. 5. Pruning of unnecessary tomato shoots.

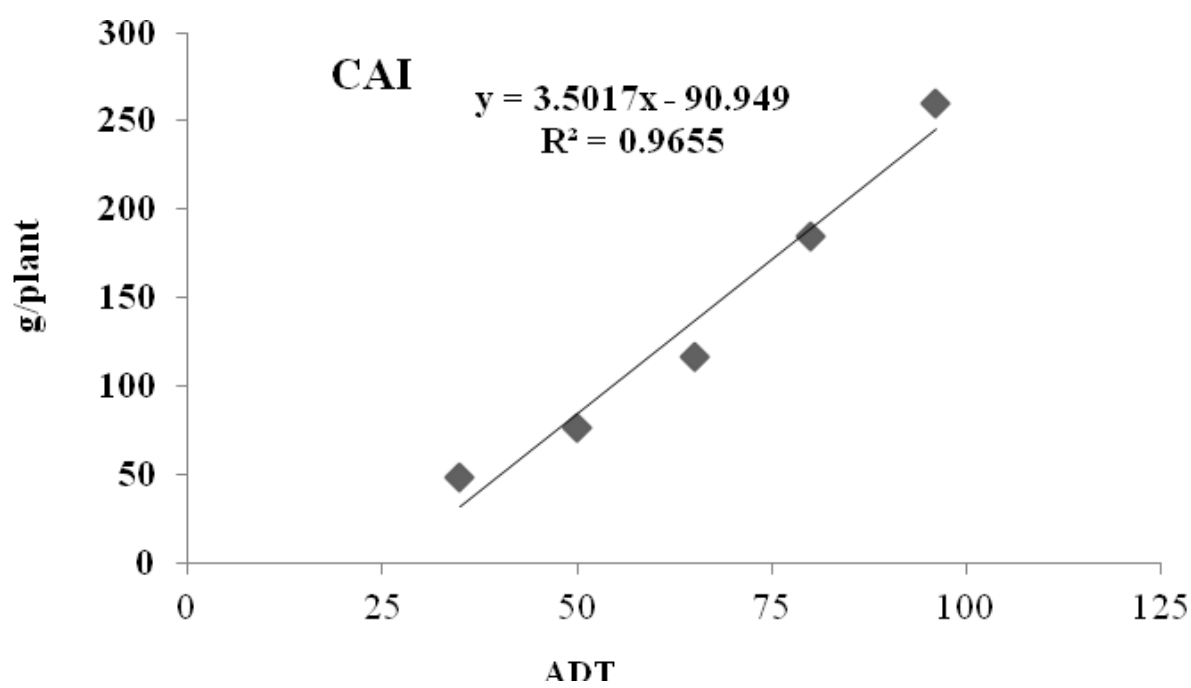


Fig. 6. Dry matter and total accumulated average in CAI: Caiman; DM A: Dry Matter average; ADT: After day trasplanting.

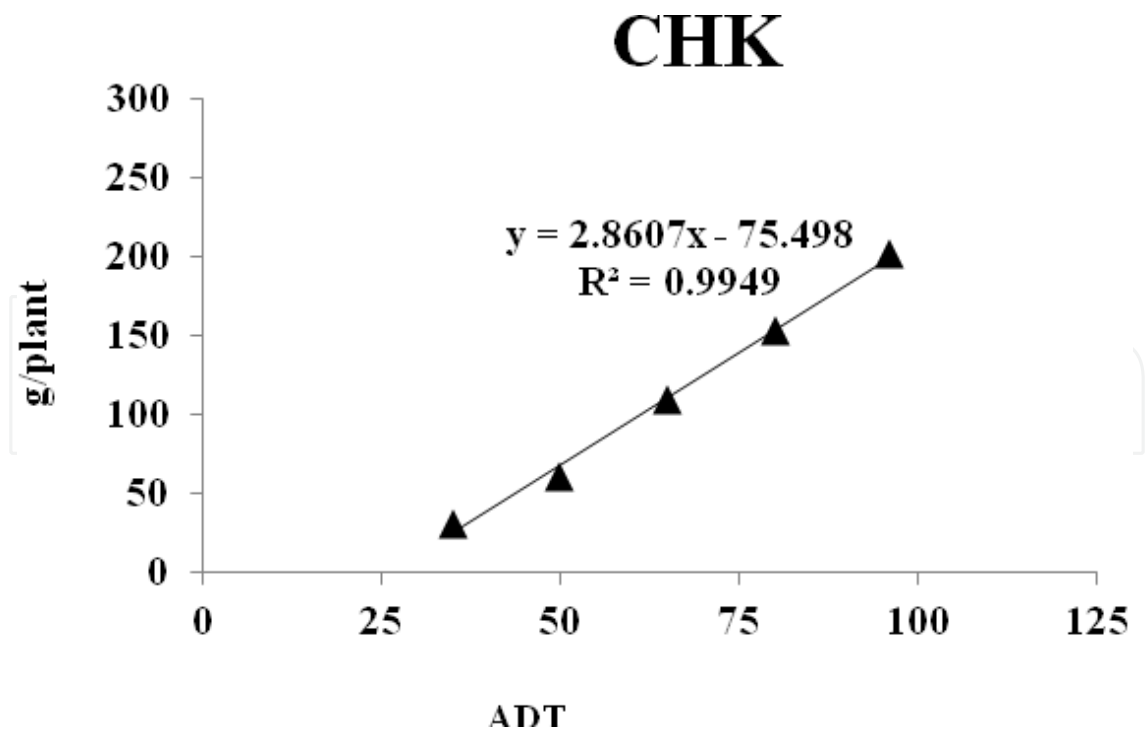


Fig. 7. Dry matter and total accumulated average in CHK: Charleston Korean; DM A: Dry Matter average; ADT: After day trasplanting.

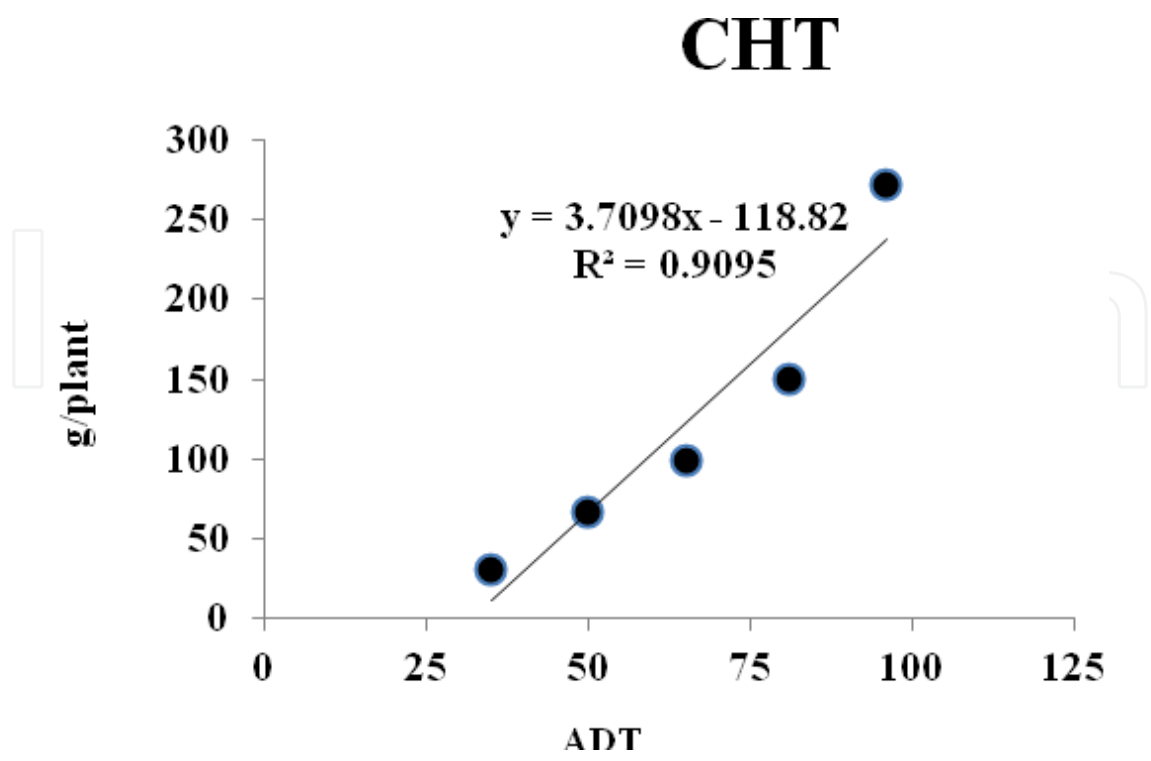


Fig. 8. Dry matter and total accumulated average in CHT: Charleston Tunnel; DM A: Dry Matter average; ADT: After day trasplanting.

ADT	DMA (g/plant)			
	CAI	CHK	CHT	Average
35	48.69	30.77	30.77	36.74
50	76.81	60.47	66.66	67.98
65	116.16	108.98	98.76	107.96
80	184.80	153.06	150.00	162.62
96	260.32	201.80	272.77	244.96
R²	0.9655	0.9949	0.9095	0.9672
Rate of Increase of MS g/day/plant	3.5017	2.8607	3.7098	3.3699

Table 1. Dry matter and total accumulated average in two hybrid tomatoes. CAI: Caiman; CHK: Charleston grown in Korean greenhouse; CHT: Charleston in tunnel; DMA: Dry matter average (g/plant). ADT: after day transplanting.

Figure 9 shows the estimated model with the average values in the three systems evaluated, if there were some mathematical models of nutrient removal, we could estimate the dose for each nutrient to apply, once it has the most of the nutrients, it is possible calculate a fertilization program for growing tomatoes, a further advantage of this procedure is that it could adjust fertilization with irrigation, if available, a pressurized irrigation system.

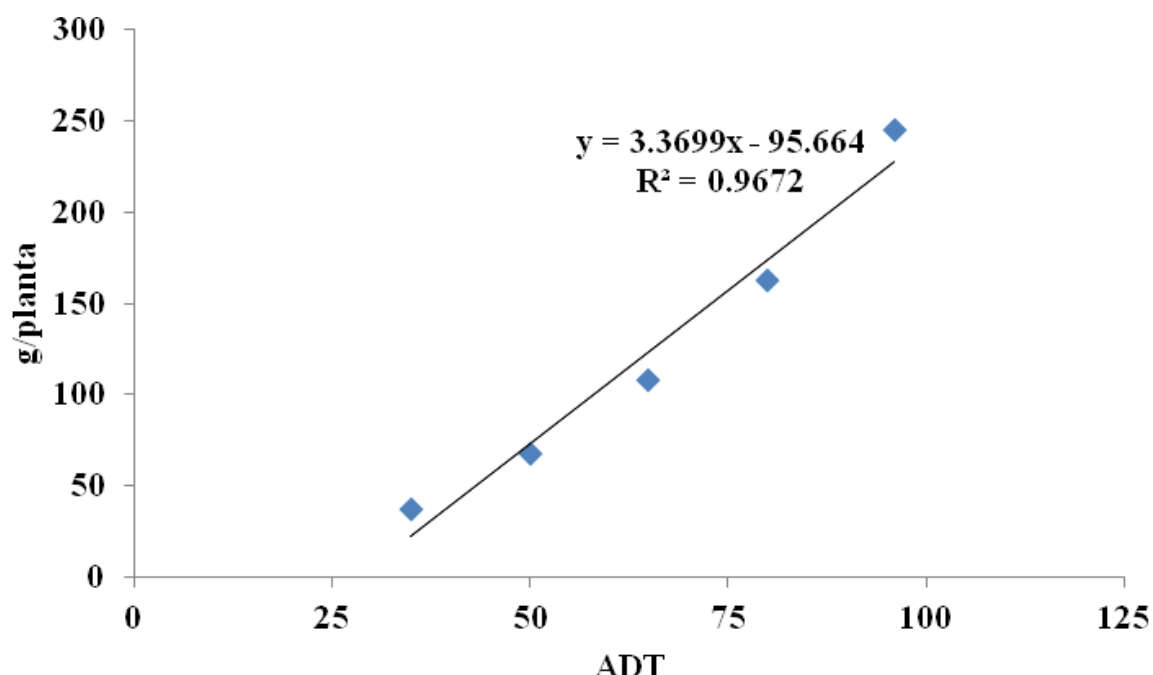


Fig. 9. Linear model obtained from total dry matter considering both hybrids.

5. Conclusion

Although the stage of harvest of tomato is not completed successfully because of environmental factors, It was possible to estimate dry matter production, the rate of increase in dry matter was higher and similar for CAI and CHT, but was lower for CHK. The average yield of the two hybrids was considered adequate to estimate dry matter production in tomato crop in this geographical area. Once we determined the removal of nutrients such as nitrogen, phosphorus, potassium, among others, and generate models of extraction of these, it can be calculated the amount of each nutrient applied and thus may establish a program of fertilization to ensure a sustainable production system; such program may be adjusted by several cycles of this same culture.

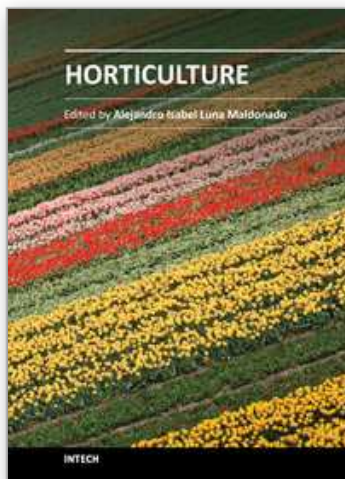
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