Methodological proposal for three-dimensional modeling of tomato plant in greenhouse and the optimization of spray application by computational fluid dynamics (CFD) techniques.

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1.OBJETIVES

- To develop a 3D model of a tomato plant in greenhouse type “raspa y amagado”, in their different growth stages
- Simulations of spray using Computational Fluid Dynamics (CFD) techniques,
- To develop a methodology to simulate the process of spray pesticides in greenhouses, in order to get a tool to optimize the deposition of products on the plant and reduce the doses used.

2. MATERIALS AND METHODS

3D Plant model

A magnetic 3d digitizer (Polhemus FASTRAK) (Fig. 1a) was used

- Determination of the optimal work distance to get an error lower than 1,5 cm (Fig. 2)
- Digitization of stem, leaves, flowers and fruits (SOFTWARE: FLORADIG) (Fig 1b,c,d).
- Obtaining the 3D plant model

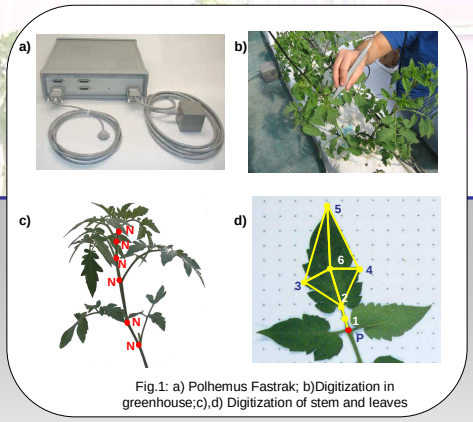

Fig.1: a) Polhemus Fastrak; b)Digitization in greenhouse;c),d) Digitization of stem and leaves

Model accuracy

- 3D representation was compared with a real image (Fig. 3).
- The estimated height value was compared with real one (Table 1).
- The estimated indexes TRV (Tree Row Volume) and LAI (Leaf Area Index) were compared with real ones (Table 2, 3).

CFD Model

- FLUENT software (Ansys Fluent Inc.) was used to simulate the process of spraying
- A flat fan nozzle TP9501E (Teejet) was calibrated using this software for a fixed pressure (2 bar), which was subsequently used for spraying simulation in a 3D model of tomato plant.
- The nozzle calibration was done by comparing the simulated data about the distribution of drop size with the real ones, to select the simulation in which the droplet size distribution is closer to the actual data (Table 4, Fig. 4). These real data were obtained using a laser particle size distribution analyzer. Many simulations were done and, in each one, parameters of FLUENT injection configuration were changed (“Sheet” and “Spread factor”)

3. RESULTS AND DISCUSSION

Work distance to get an error lower than 1,5cm = **101,7cm**

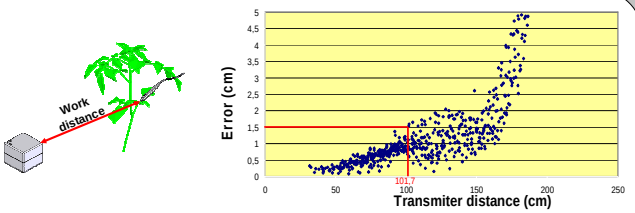

Fig.2: Work distance to get an error lower than 1,5cm

Accuracy of the 3D model

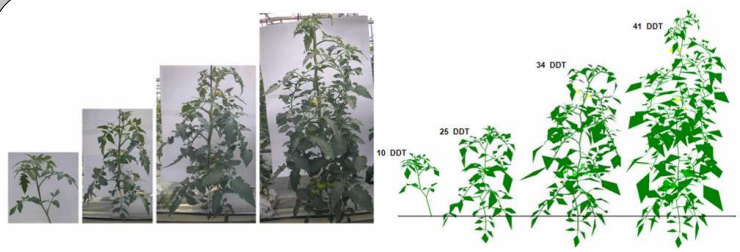

Fig.3: Comparison of real plants vs. 3D model plants

Table 1 . Comparison of real height vs. digitized height

DDT	Real Height (cm)	Digitized Height (cm)	Error (%)
10	28.5	26.4	5.61
25	51.5	48.5	5.82
34	76.5	73.3	4.18
41	99	93.7	5.35

Table 2. Comparison of real TRV vs. digitized TRV

DDT	Real TRV (m^3/ha)	Digitized TRV (m^3/ha)	Error (%)
10	213.75	196.68	7.99
25	1100.81	1097.31	0.32
34	2075.06	1925.96	7.19
41	2970.00	2767.54	6.83

Table 3. Comparison of real LAI vs. digitized LAI

DDT	Real LAI (m^3/ha)	Digitized LAI (m^3/ha)	Error (%)
10	0.129	0.124	3.870
25	0.320	0.309	3.474
34	0.632	0.656	-3.67
41	1.174	1.124	4.26

CFD Model

Table 4. RSE values obtained for presure of 2bar

Sheet	“Spread factor” = 3.5		
	Standard Relative Error (%)		
	Dv_{100}	Dv_{95}	Dv_{90}
14	18.79	13.65	14.35
15	17.45	12.07	12.26
16	19.45	12.38	12.58
17	17.89	10.56	10.15
18	18.21	9.39	**8.15**
19	18.93	12.48	12.43

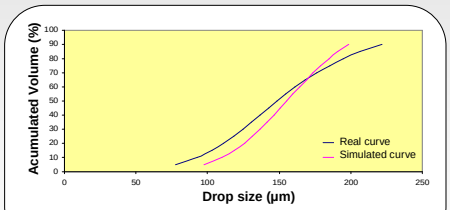

Fig.4: Comparison of distribution of real drop size vs. simulated drop size (Spread Factor=3.5, Sheet=18)

Simulation on tomato plant

The plant selected was 10ddt and the selected configuration for the simulation was a "Spread Factor" = 3.5 and a "Sheet“ = 18, because the RSE was the smallest (Fig. 5)

Table 5. Amount of product retained by the plant

Sprayed Product (g)	Retained product (g)	%
2.22	0.14	6.45

Only 6.45% of the total amount applied is deposited on the plant due to its small size, and therefore much of the sprayed product doesn't achieve the target.

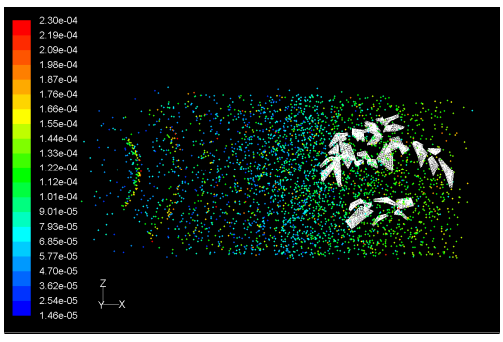

Fig.5: Trajectories of the injected droplets colored depending on diameter.

4. CONCLUSIONS

The 3D plant model provides a good estimation to the plant biomass. Finally, a spray simulation was done on the 3D model, allowing to quantify the fluid fraction retained by the plant with a low cost, and avoiding the performance of field trials.

3th Precission Crop Protection

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