Yield gaps estimation for greenhouse tomato crops in Uruguay.

C. Berrueta [a,*], E. Heuvelink [b], G. Giménez [a], S. Dogliotti [c]

[a] Programa de Horticultura, Instituto Nacional de Investigación Agropecuaria Las Brujas, Ruta 48 Km 10 (90200), Rincón del Colorado, Uruguay.
[b] Horticulture and Product Physiology, Wageningen UR, Droevendaalsesteeg 1 6708 PB, Wageningen, The Netherlands.
[c] Departamento de Producción Vegetal, Facultad de Agronomía, Universidad de la República, Garzón 809 (12900), Montevideo, Uruguay.

* Corresponding author: (cberrueta@inia.org.uy)

1. Introduction

Yield gap analysis is a powerful method to explore gap's breadth between potential yields, attainable and those realized in farmers' fields, identifying constraints and opportunities for yield increase. Understanding and ranking the main causes of yield gaps is essential to provide feedback to farmers and extension agents, contributing to reduce both yield gap and yield variability between farms (Lobell et al., 2009). This paper aims to quantify yield gaps in greenhouse tomato crops in the south region of Uruguay and assess opportunities for increasing tomato production by modifying those factors defining potential yield or "yield defining factors" (Van Ittersum and Rabbinge, 1997).

2. Materials and methods

We assessed yield and yield components across seasons, in 110 greenhouse tomato (*Solanum lycopersicum*) crops (indeterminate beef tomato varieties) during 2014/15 and 2015/16 in the south region of Uruguay and compared them with potential and attainable yield. We distinguished 5 types of tomato crops defined by transplanting date and length of cropping cycle (Table 1).

Table 1. Description of crop cycle types and number of crops.

Crop cycle type	Crop period length (days)	Transplanting date	Number of crops
Short spring	< = 200	1st July until 30th September	33
Short autumn	< = 200	1st January until 31th March	30
Short summer	< = 200	1st October until 31th December	11
Long winter	> 200	1st February until 31th March	5
Long summer	> 200	1st August until 31th December	31

Potential yield was calculated with a simulation model based on photosynthetic active radiation (PAR) and light use efficiency, and TOMSIM to estimate assimilate partition and fruit yield. Since yield was primarily determined by cumulated PAR intercepted, a boundary function was fitted to estimate attainable yield as a function of cumulated PAR intercepted.

3. Results and Discussion

Potential, attainable and actual yields for each crop are shown in Fig. 1. The gap between actual and potential yield considering a greenhouse transmissivity of 70% (PY70) was on average 10.7 kg m^{-2} or 44% of PY70. Average gap was higher for short summer and spring crops (57%), than for long summer crops (46%) and short autumn crops (24%). Overall gap was divided into three components: difference between actual and attainable (45% of total gap), attainable and potential with actual greenhouse PAR transmissivity (29% of total gap) and between potential with actual transmissivity and potential with 70% of greenhouse transmissivity (26% of total gap) (Fig. 2).

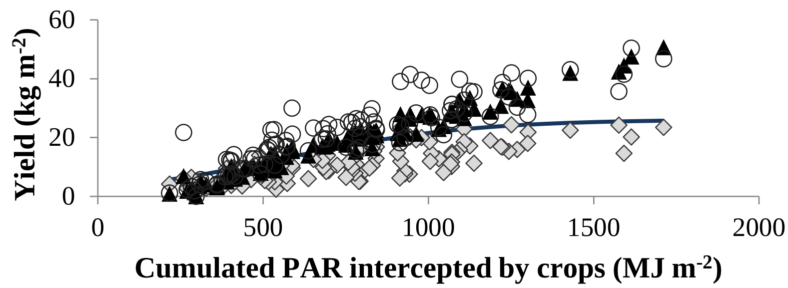

Fig. 1. Actual (◇), simulated potential considering a greenhouse transmissivity of 70% (○), simulated potential considering real greenhouse transmissivities (▲) and attainable yield (fitted boundary line for actual yields, $y_i = 26.16 / (1 + (7.81\ e^{-0.0036\ x_i}))$, as a function of cumulated PAR intercepted by crops (with real greenhouse transmissivity), R^2 adjusted: 0.95, N = 109.

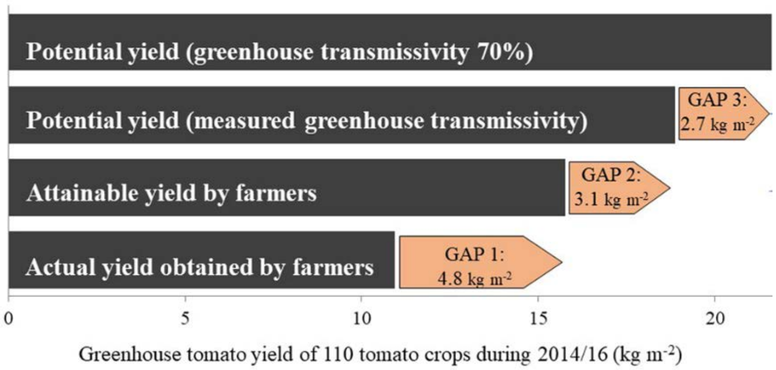

Fig. 2. Production levels: actual, attainable, potential with measured greenhouse transmissivity, potential with 70% of greenhouse transmissivity and yield gaps (1, 2 and 3).

Cumulated PAR intercepted was the variable most highly correlated with yield (Spearman correlation coefficient: 0.8, p-value: <0.0001). PAR intercepted depends on daily incident radiation, crop period length and leaf area index (LAI) (Heuvelink et al., 2005). Daily incident radiation is affected by seasonal differences due to transplanting dates and crop duration. On average spring and summer crops had 42% more incident light explaining their higher potential yield. Another factor affecting incident radiation was greenhouse transmissivity, which was 62 ± 11% on average and was affected by the age of the plastic (Spearman correlation coefficient: -0.52, p-value <0.0001) and use of whitening, shading netting or thermal covers. Light interception shows a saturating response to LAI, with about 90% of the incident light intercepted, at a LAI of 3.0 (Heuvelink, 1996). Average observed fraction PAR intercepted was 70% during the harvesting period, 22% lower than target. For short spring and summer crops the observed fraction PAR intercepted was lower than simulated during the whole growth period, and from third truss initial fruit development for long summer crops (95% confidence) (Fig. 3a and 3c). In short autumn crops, observed fraction PAR intercepted was similar to simulated before harvest beginning (95% confidence). After that, fraction PAR intercepted was significantly lower than simulated (Fig. 3b). Fraction PAR intercepted at first ripe fruits and middle of harvest were negatively correlated with leaf removal intensity (Spearman correlation coefficient: -0.29 and -0.37, p-value: 0.0303 and 0.0059, respectively).

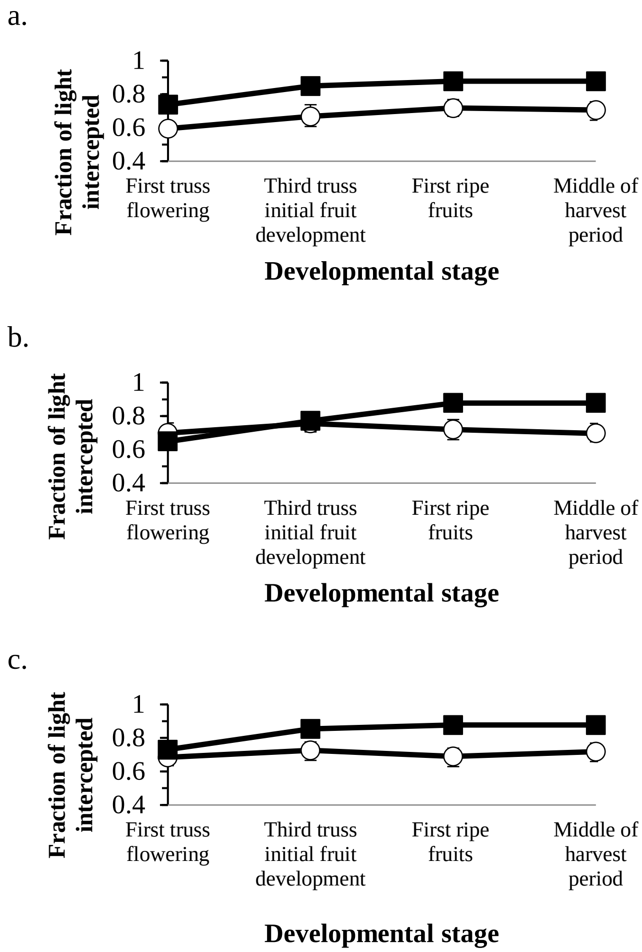

Fig. 3. Average observed (o) and simulated (■) fraction of light intercepted at first truss flowering, third truss initial fruit development, first ripe fruits and middle of harvest period, for short spring/summer (a), short autumn (b) and long summer crops (c). Vertical bars: 95% confidence interval for the mean. N = 44, 30 and 31, respectively.

4. Conclusions

Large yield gaps were detected in tomato greenhouse crops in Uruguay and closing these gaps is a challenge. For long summer and short spring/summer crops the greatest impact in yield could be obtained by increasing leaf area index by reducing plant lowering operations and leaf pruning intensity, and by increasing plant density. For autumn crops, yield could be improved by earlier planting, reducing leaf pruning intensity after harvest beginning, and increasing greenhouse transmissivity by more frequent plastic cover renewal and removing roofs' shading screens and whitening.

References

Heuvelink, E., 1996. Dry matter partitioning in tomato: validation of a dynamic simulation model. Ann. Bot. 77, 71–80.

Heuvelink, E., Bakker, M.J., Elings, A., Kaarsemaker, R., Marcelis, L.F.M., 2005. Effect of leaf area on tomato yield. Acta Hortic. 691, 43–50.

Lobell, D.B., Cassman, K.G., Field, C.B., 2009. Crop yield gaps: their importance, magnitudes, and causes. Ann. Rev. Environ. Res. 34, 179-204.

Van Ittersum, M.K., Rabbinge, R., 1997. Concept of production ecology for analysis and quantification of agricultural imput-output combination. F. Crop. Res. 52, 197–208.