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Use of Proximal Optical Sensors for Assessing Crop N Status of Vegetable Crops

Francisco M. Padilla

Department of Agronomy
University of Almeria
f.padilla@ual.es

http://www.ual.es/GruposInv/nitrogeno/padilla_personal.shtml

Proximal optical sensors for N management

- Sensors that provide indirect estimate of crop N status from measurement of light properties of crops that are sensitive to crop N content
- They do not measure N content in plant tissues
- Measurements are taken in close contact with the leaf or very close to the plant canopy → Proximal sensors
- More use in cereal crops in the USA and northern Europe than in vegetable crops

- **Our research program deals with the evaluation of different optical sensors to assess crop N status and yield and to guide N fertilization**

Optical sensors studied or being studied

- Leaf chlorophyll meters

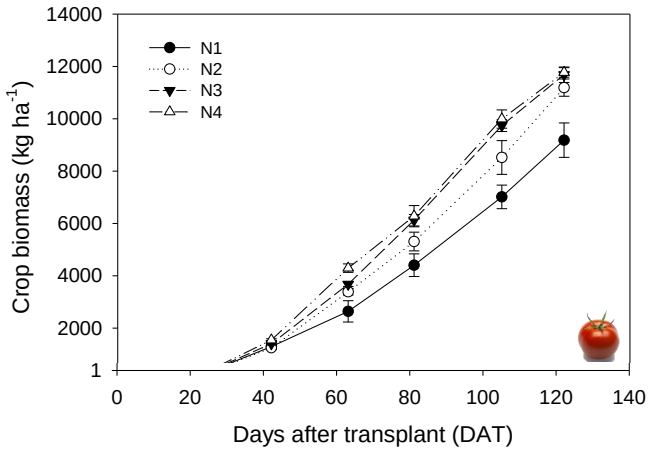
- Canopy reflectance sensors

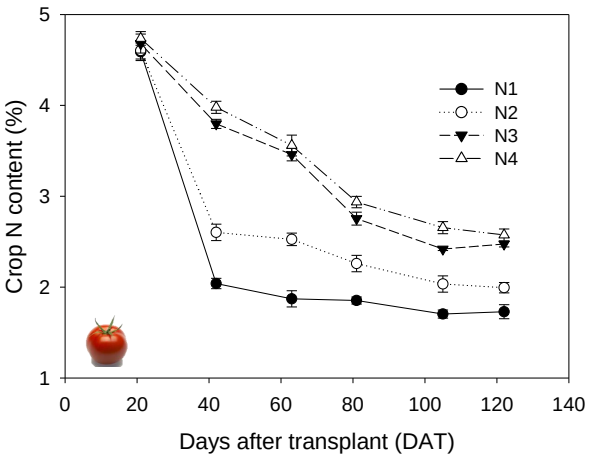
- Fluorescence sensors or fluorimeters (Multiplex, DUALEX)

Methodology - Proximal optical sensors

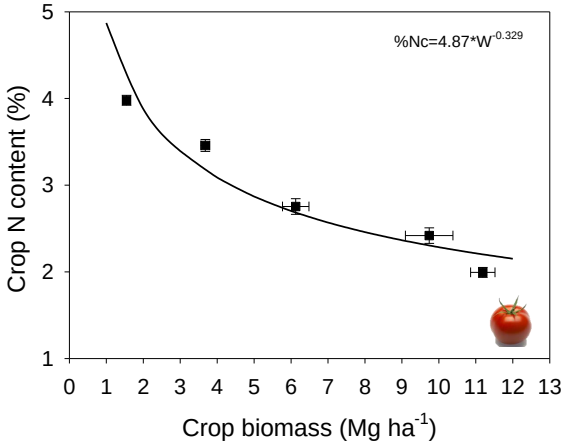
1) Crop grown with 4–5 rates of N; applied as different N concentration throughout crop

2) Periodic determinations of *crop biomass* and *total crop N content*

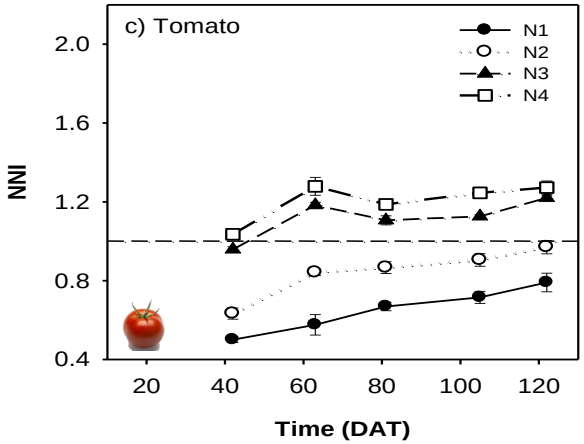




3) Critical N curve determined

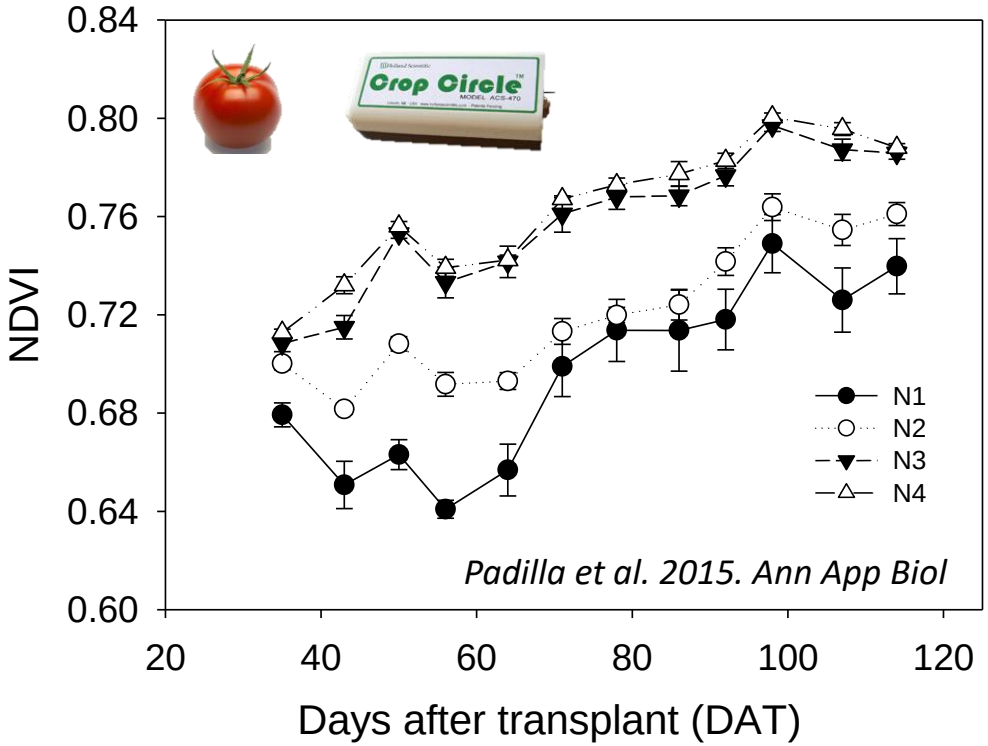


4) NNI (Nitrogen Nutrition Index)



Methodology - Proximal optical sensors

Weekly measurements with optical sensors during the crop



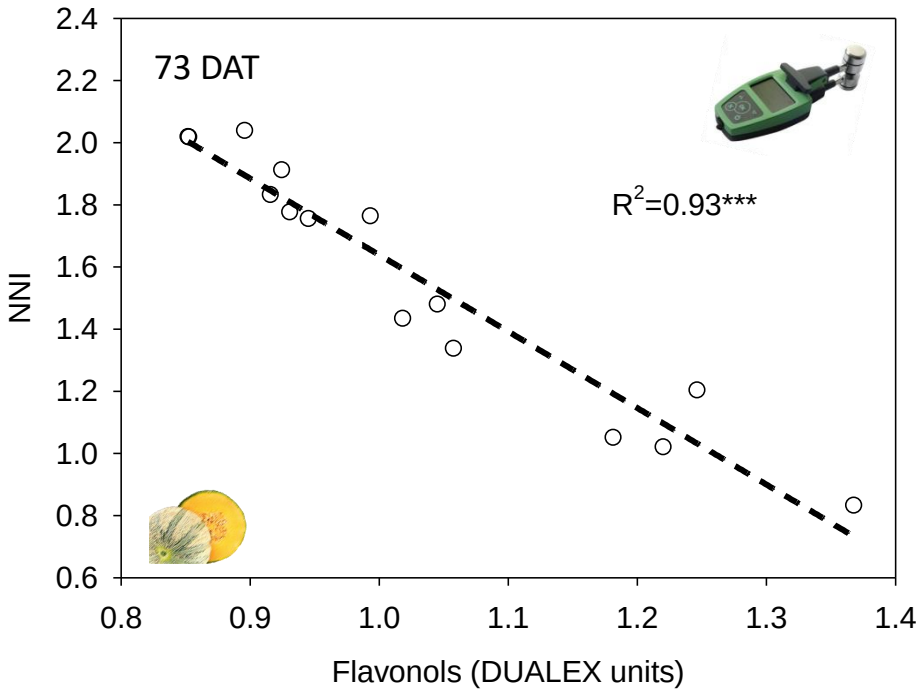
NDVI: **N**ormalized **D**ifference **V**egetation **I**ndex = $\frac{NIR - Red}{NIR + Red}$

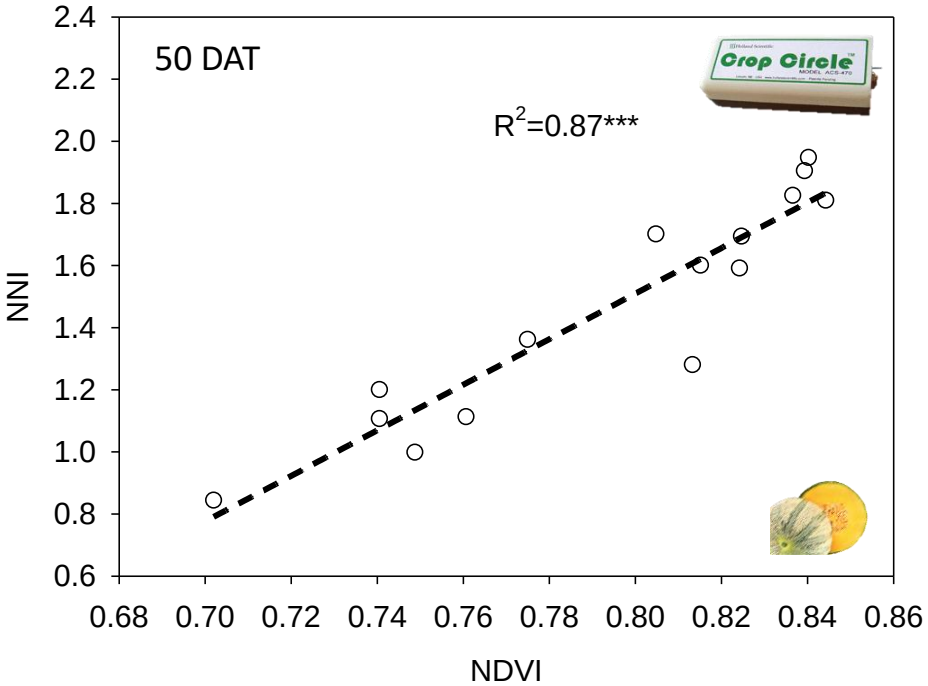
What is our approach to evaluate proximal optical sensors as indicators of crop N?

- Determine the nature and strength of relationships (linear, quadratic, etc.) between optical sensor measurements (indices) and crop N content (%N), crop N status, as NNI, or fruit yield

- Assess the sensitivity of optical measurements as indicators of crop N status and yield from the coefficient of determination and error of prediction throughout the entire crop cycle

Example of relationships between optical sensors indices *vs.* crop NNI

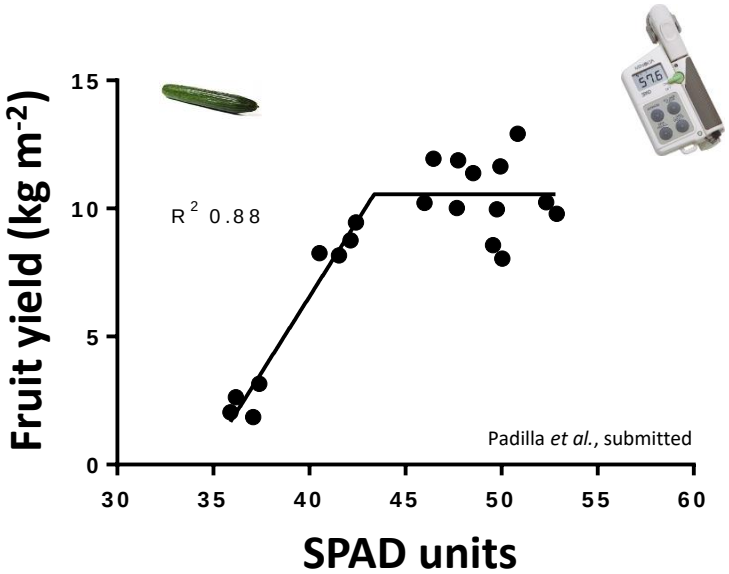


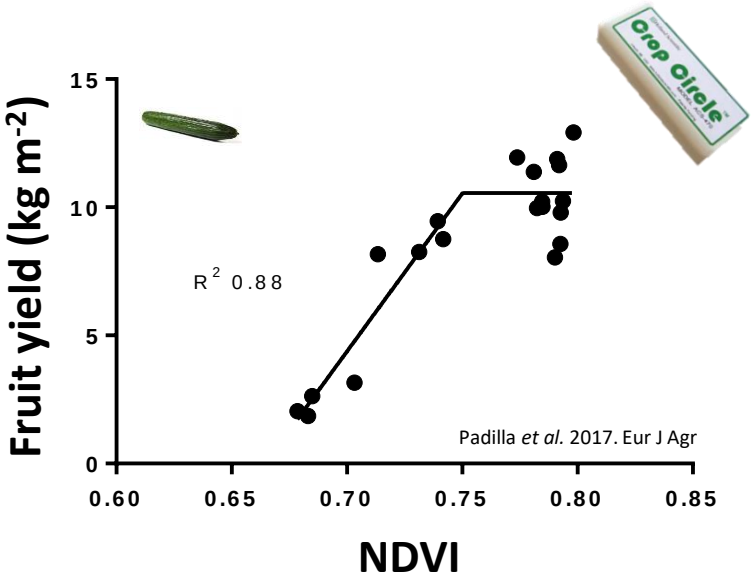


NDVI: **N**ormalized **D**ifference **V**egetation **I**ndex

Padilla et al. 2014. Eur J Agr

Example of relationships between optical sensors indices *vs.* fruit yield

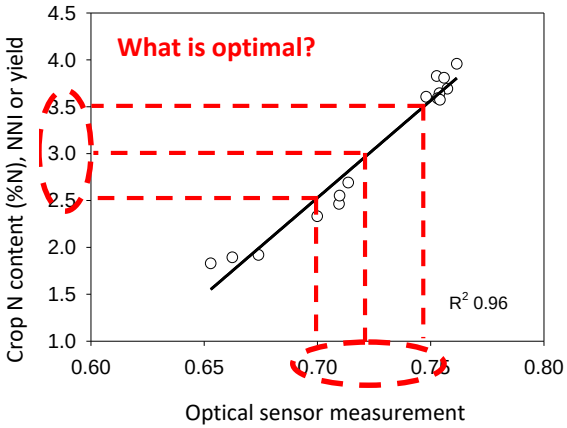




How can we use sensors measurements to assess crop N on farm and guide fertilization?

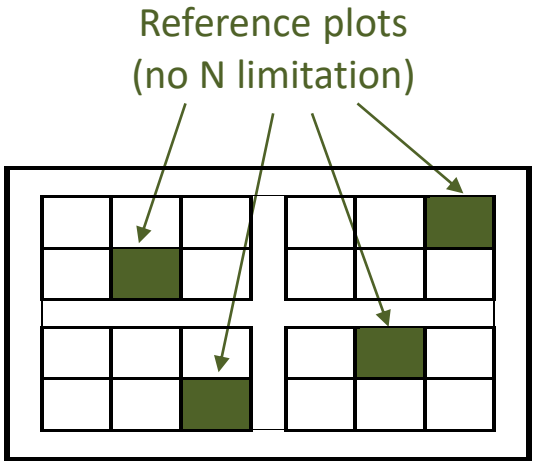
- Our research program over the last eight years has shown that optical sensors measurements are good and reliable indicators of crop N status and yield in several species (muskmelon, tomato, cucumber sweet pepper)…

- But absolute sensors' measurements are of little help if we do not know what the optimal values are (i.e., sufficiency values)



Traditional approach to interpret sensors measurements and to guide N fertilization

- Relative approach → Reference plots: establishment of well-fertilized reference plots without N limitations

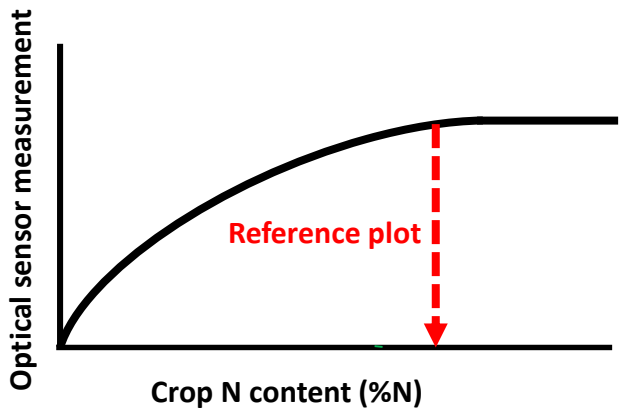


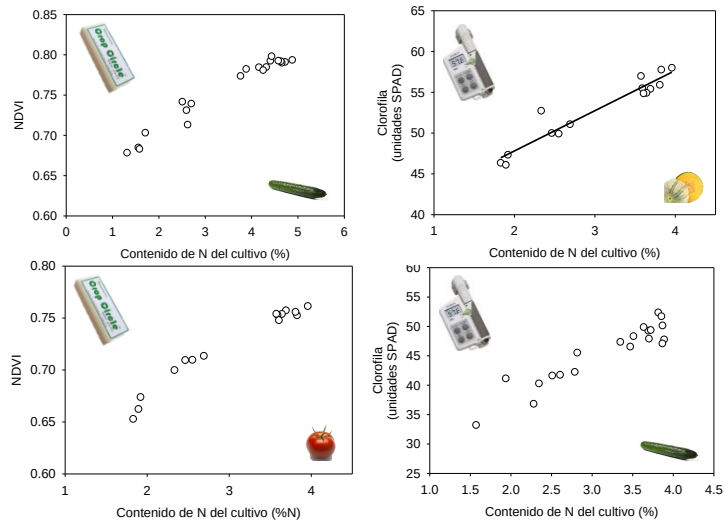
- $Sufficiency\ Index\ (SI) = \frac{Crop\ measurement}{Reference\ plot\ measurement}$ x 100

- Crop is N defficient whenever *SI* is < 90-95%

But there are some limitations with reference plots

- Scientific limitations
  - Assumes optical sensor measurements saturates at optimal N doses
  - Our experience shows that saturation does not always occur





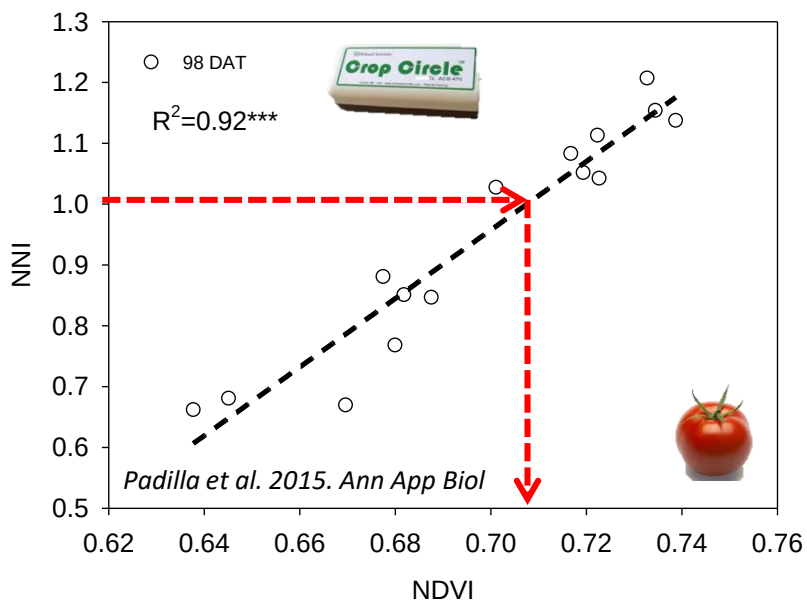
- Technical limitations
  - It is costly to establish reference plots in fertigated plots because of the need of installation of differentiated irrigation sectors

Alternative? Derive absolute sufficiency values for optimal crop growth and yield

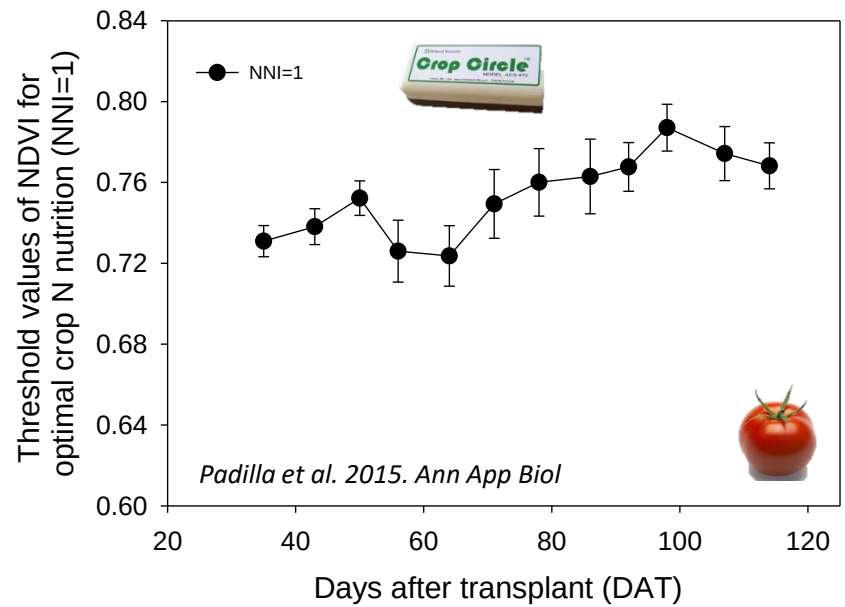
SUFFICIENCY VALUES FOR MAXIMUM CROP GROWTH

From relationships of optical sensor measurements (indices) with crop **NNI**

- Solve mathematical equations of the relationships for NNI=1 (optimal N)



Threshold for optimal crop N status at 43 DAT



Threshold values for optimal crop N nutrition throughout the crop

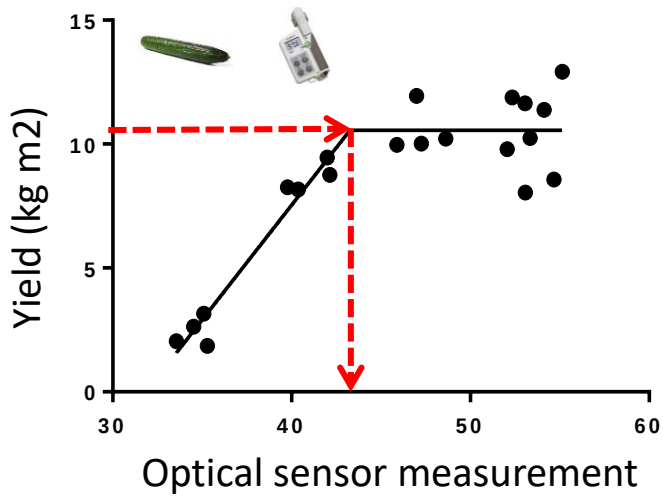
Subsequently, use sensor measurements, with these sufficiency values, to assess whether the crop status is N deficient, excessive or optimal for growth

Alternative? Derive absolute sufficiency values for optimal crop growth and yield

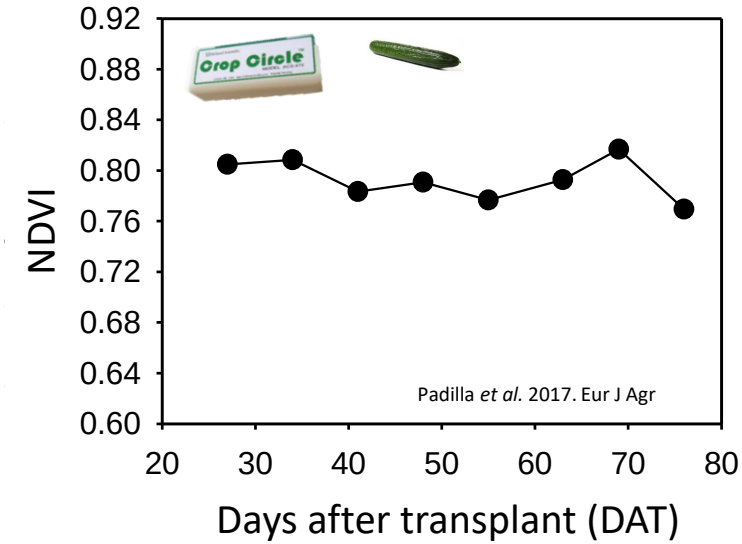
SUFFICIENCY VALUES FOR MAXIMUM YIELD

From relationships of optical sensor measurements (indices) with **yield**

- Determine the breakpoint from which yield no longer increases with optical sensor measurements



Sufficiency index for maximum yield at 57 DAT



Sufficiency Index for máximum yield for the whole crop

Subsequently, use sensor measurements, with these sufficiency values, to assess whether the crop status is N deficient, excessive or optimal for yield

Further research/challenges

- Research has shown that optical sensors are very sensitive under deficient to optimal N conditions, but further research is necessary to evaluate sensitivity particularly under excessive N conditions

- Evaluation of sensitivity under excessive N conditions is very relevant as vegetable crops are often OVER-FERTILIZED

- We are developing absolute sufficiency values for optimal crop growth and yield for given phenological phases of a given cultivar of each species, but are they consistent in other cultivars?
  - Is there a genotype effect (cultivar effect) on optical measurements and sufficiency values?

- When it comes to absolute sufficiency values, how could we deal with between-year variability in crop conditions?
  - Fortunately, it seems that between-year variability of climatic conditions in greenhouses is low

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Thank you!

Suggested bibliography

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Departamento de Agronomía, Universidad de Almeria
http://www.ual.es/GruposInv/nitrogeno/index.shtml
f.padilla@ual.es