Improving ‘Source-sink relationships’
FG- Y2

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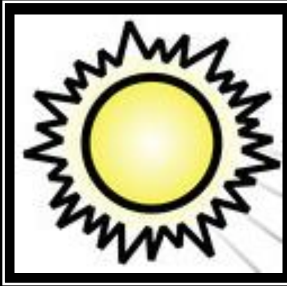
Improving source – sink relationships

leaves



C fixation

\+ → photoassimilates

roots

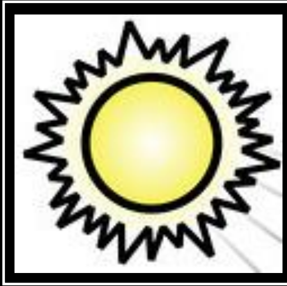
Water +
Mineral uptake

Harvestable sink organs : sink demand

Source-sink relations: old agronomic concept.
Limiting the number of sinks improves the quality and yield of the remaining sinks

Regulation of source – sink relationships

leaves



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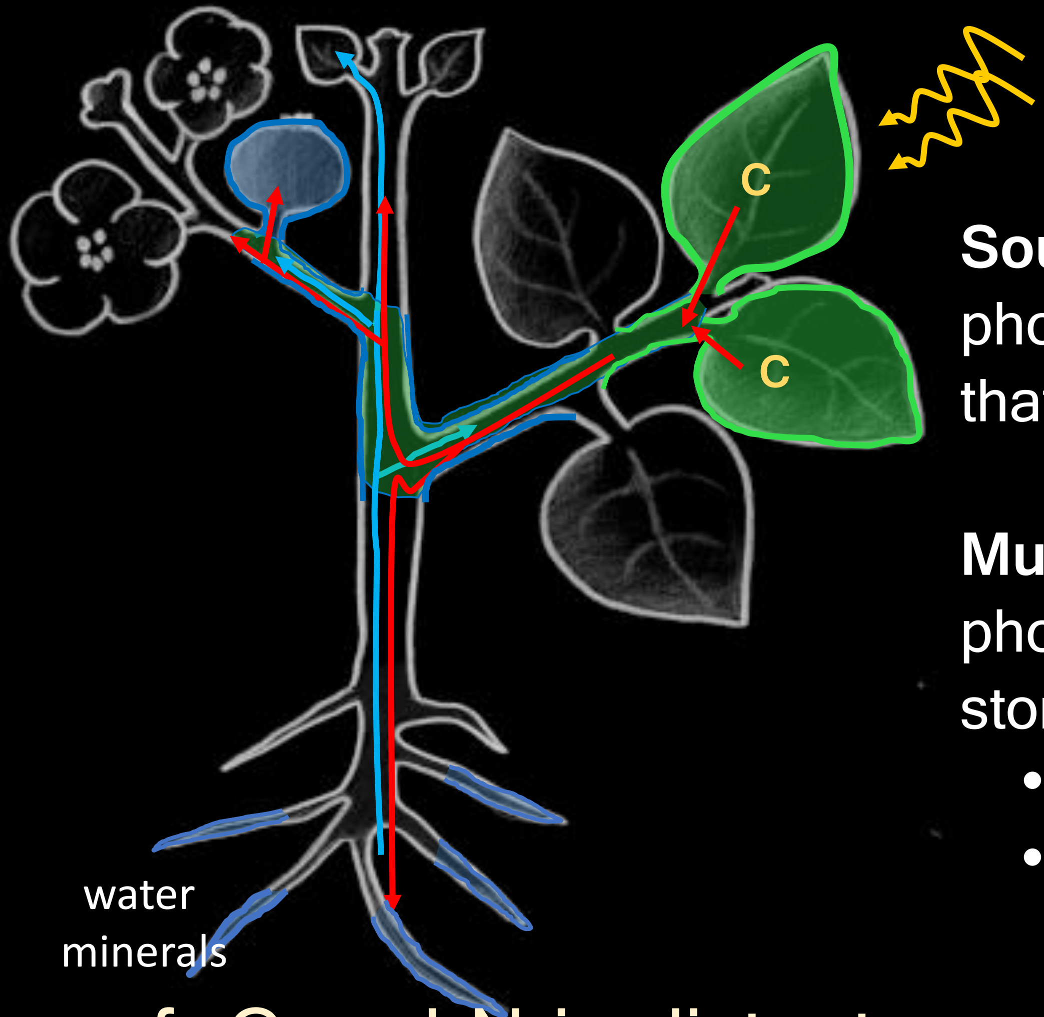


Sources:
photosynthetic organs that export C

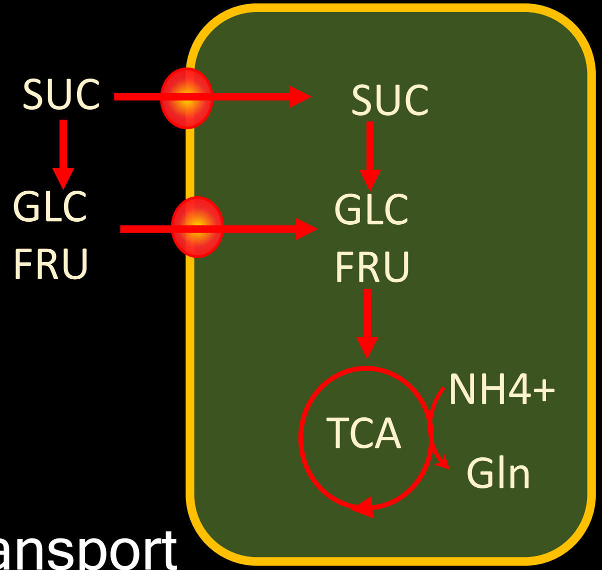
Multiple sinks:
photoassimilates used, stored or sequested

- Terminal sinks
- Lateral sinks

Allocation of C and N in distant organs.

Critical players : Phloem and Xylem

How to alter source – sink relationships?



Targeting central metabolisms and C and N transport
Ex Yield increases in potato, tomato, maize, pea

- Manipulation of **source** C and N metabolism and transport
- Manipulation of **sink** C (or N) metabolism
- Manipulation of **both source and sink** C and metabolism and transport

Additional factors have been identified or confirmed by quantitative genetic approaches

Yield is co-limited by source and sink

Inherent complexity of source-sink relationships

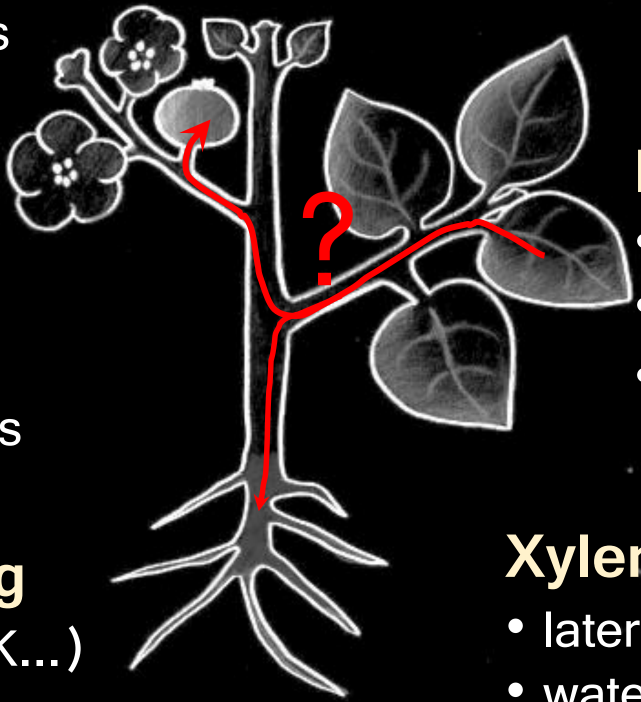
What are the best ways to increase the rate of C fixation and carbon allocation, while minimizing sink feedback or non-productive accumulation of photosynthate?

Inherent complexity of source-sink relationships

Sink development
- Increase harvestable sink organs
- Increase root development
- Produce storage metabolites

Photosynthesis in the sources
- boost metabolic reactions (central metabolism and cellular respiration) and transport

Vascular tissues
- development
- stress response
- long distance signals



Phloem long-distance transport
- sucrose & AA transport
- loading, unloading, release and retrieval
- symplasmic and apoplasmic transport

Nutrition & Signaling
- Mineral uptake (N, P, K...)
- Sugar signalling (T6P)
- N signalling

Xylem and phloem exchanges
- lateral transfer of nutrients
- water transport
- lateral transfert of water

Inherent complexity of source-sink relationships

FG-Y3
FG-Y4
FG-S4
FG-N5

Sink development

- Increase harvestable sink organs
- Increase root development
- Produce storage metabolites

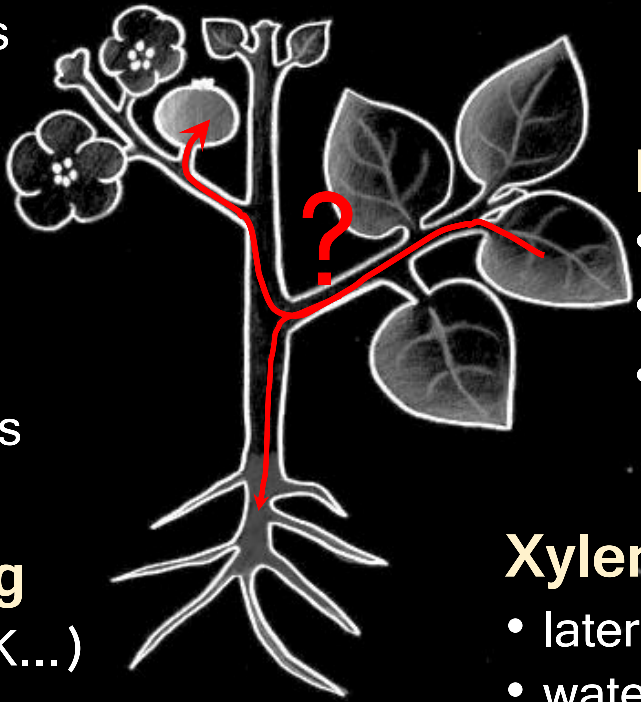
Photosynthesis in the sources

FG-Y1

- boost metabolic reactions (central metabolism and cellular respiration) and transport

Vascular tissues

- development
- stress response
- long distance signals



Phloem long-distance transport

- sucrose & AA transport
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FG-S1
FG-S2
FG-S4
FG-S6

Nutrition & Signaling

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- Sugar signalling (T6P)
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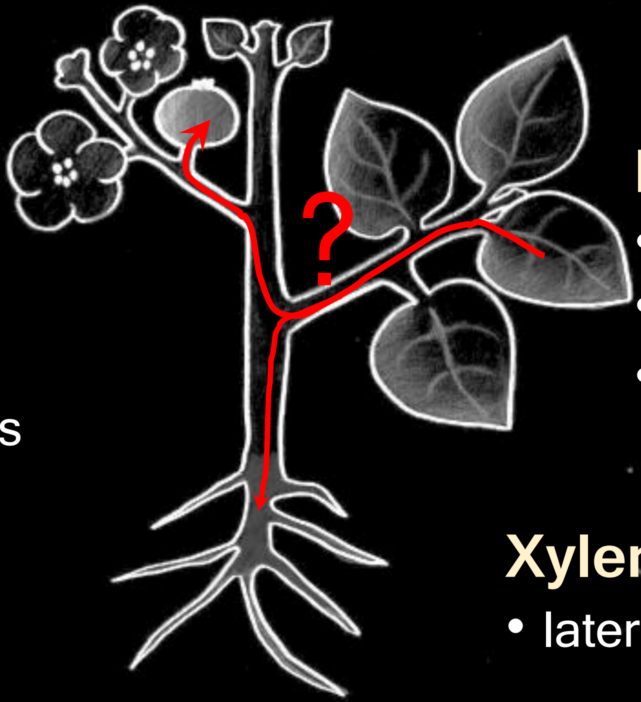
Xylem and phloem exchanges

- lateral transfer of nutrients
- water transport
- lateral transfert of water

FG-S3

Inherent complexity of source-sink relationships



Vascular tissues
- development
- stress response
- long distance signals

Phloem long-distance transport
- sucrose & AA transport
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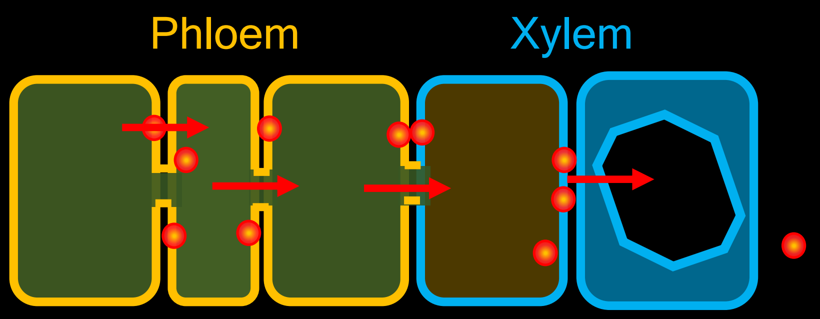
Xylem and phloem exchanges
- lateral transfer of nutrients

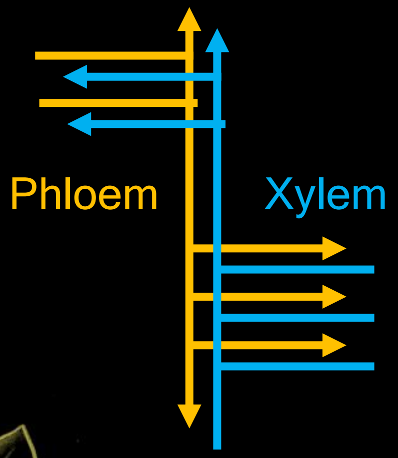
... Still many bottlenecks limiting growth rate and yield

Future challenges for source-sink relationships



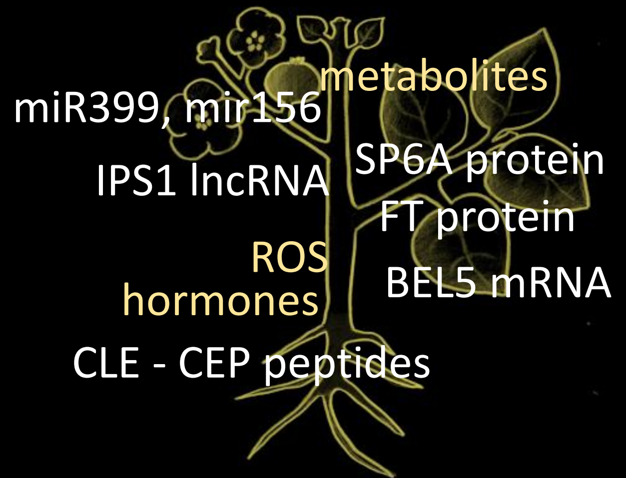
Cell level (phloem and xylem cells)

- Transport, Metabolism, Sensing, Signaling and Regulation (single-cell approaches)



Intermediate scale: Vascular tissues

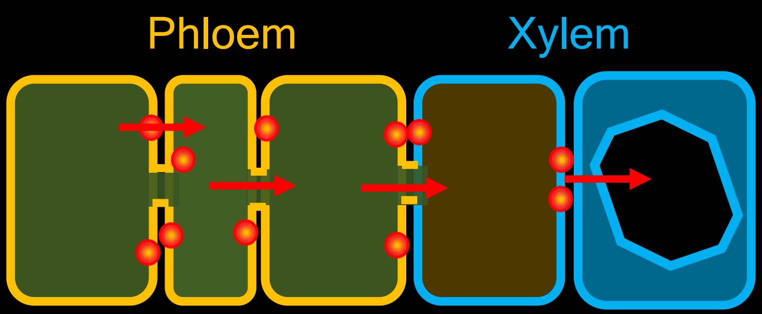
- Dynamics of transport, development of phloem, function of vascular parenchymas, frequency of PD and transporters



Inter-organ level

- Long-distance transport signaling
- Non-cell autonomous systemic control
- Organ-dependent
- Environmental constraints

Future challenges for source-sink relationships



Some of the questions to be addressed:

- Mechanisms
- Plasticity and regulation of C and N allocation
- Impact of agriculture practices

- What controls the rate of phloem loading?
- Are there signals from the sink that regulate loading?
- How do PDs and transporters for C and N ‘talk’ to each other? (switch apoplasmic-symplasmic)
- How is the export of sucrose co-ordinated with that of aminoacids and ions?
- What signals coordinate source and sink activities?
- What determine the differences between vegetative and reproductive sinks?
- For perennial crops, whare are the long term effects on the stability of their performance, over consecutive years

- plus many more....

(see also Fernie et al., Nature Plants, 2020)

What are the needs for innovation in crops?

Combine relevant traits for selection
source & sink traits – related to yield or quality for the selection of new elite genotypes
Applications for breeding or association studies

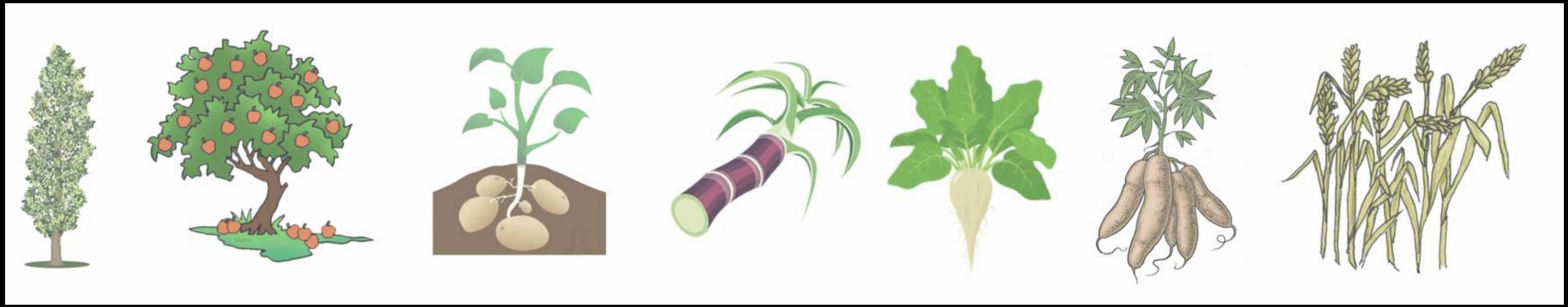
Identify traits to predict sink growth
Optimize agronomic practices

Predictive framework for mathematic modelling in crops

- Harvested sinks, tubers, taproot, fruits, seeds, grain, woodstock, cane ...
- Perennial vs annual crops
- Integrating environment constraints, genome-scale metabolic models

Action points for a future research program in the field

"one-size-fits-all" engineering approach may not work for all species



- Need for community efforts on model plants and target crop species
- Via selective breeding, identification of innovative traits relevant to source-sink relationships (source-sink ratios under stress, crop cycle duration, flag-leaf longevity...)
- Field validation of the relevant strategies for plant breeding (multisite experimentations, contrasting field environment), large genotype panels representing genetic diversity ...)
- Via genetic modification (multi-gene targeting strategies) associated with dialogue for public acceptance of gene editing technologies (NBT)
- Concerted european approach to progress efficiently

Acknowledgments

Focus Group ‘Source-sink relationships’

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