Optimizing Source–Sink Relationships for Sustainable Crop Productivity

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ABSTRACT

Global agriculture must increase crop production while ensuring the sustainable use of available resources. Improving crop productivity depends not only on the genetic potential of crops but also on the efficient production, translocation and utilization of photoassimilates within the plant. The source–sink relationship plays a vital role in regulating crop growth, yield and quality. The source, mainly mature green leaves, produces carbohydrates through photosynthesis, while the sink includes developing grains, seeds, fruits, roots and tubers that utilize or store these assimilates. Maintaining a proper balance between source capacity and sink demand ensures efficient dry matter partitioning and higher harvestable yield. Agronomic practices such as balanced nutrient management, optimum plant population, efficient irrigation, foliar nutrition, canopy management and the use of plant growth regulators help improve source efficiency and sink strength. In addition, breeding approaches aimed at enhancing photosynthetic efficiency and sink capacity offer new opportunities for sustainable yield improvement. Thus, effective source–sink management enhances resource-use efficiency, improves crop productivity and quality and

contributes to long-term food and nutritional security.

INTRODUCTION:

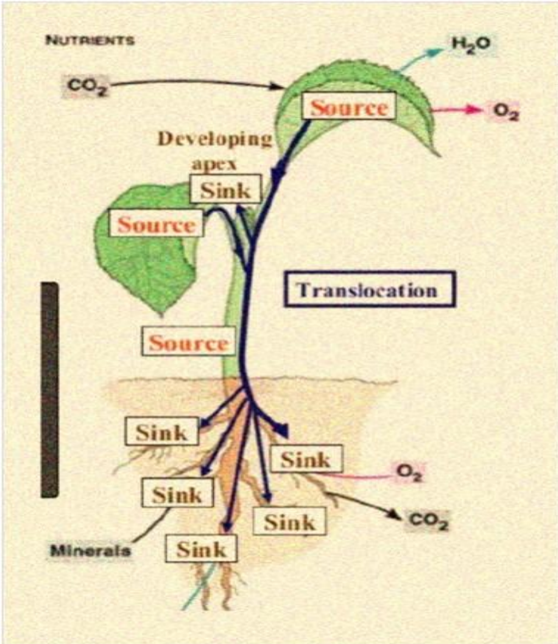
Agriculture is essential for ensuring global food and nutritional security, but increasing crop productivity has become challenging due to climate change, shrinking cultivable land, water scarcity and various biotic and abiotic stresses. Under these conditions, improving the efficiency of photosynthate production, translocation and utilization has become a key strategy for sustainable crop production. In plant 92.94% dry matter comes from photosynthesis and 6 to 8% comes from mineral matter (Wardlaw, 1990). Crop yield depends not only on biomass production but also on the efficient distribution of assimilates to economic plant parts such as grains, seeds, fruits, tubers and roots. This process is regulated by the source–sink relationship, where mature leaves (source) produce carbohydrates through photosynthesis and developing organs (sink) utilize or store them for growth and yield (Marcelis *et al.,* 1998)

Maintaining a balanced source–sink relationship through practices such as balanced nutrient management, optimum irrigation, canopy management and stress mitigation improves assimilate partitioning, resource-use efficiency and crop productivity (White and Rogers*,* 2020). Thus, effective source–sink management is an important approach for achieving sustainable agriculture and ensuring future food security.

SOURCE-SINK RELATIONSHIP

The source–sink relationship describes the movement of photosynthetically produced assimilates, mainly sugars, from sites of production (sources) to sites of utilization or storage (sinks). This continuous process determines how efficiently plants convert sunlight into harvestable yield and is therefore one of the most important physiological processes influencing crop productivity (Taiz *et al.,* 2018).

WHAT IS A SOURCE?

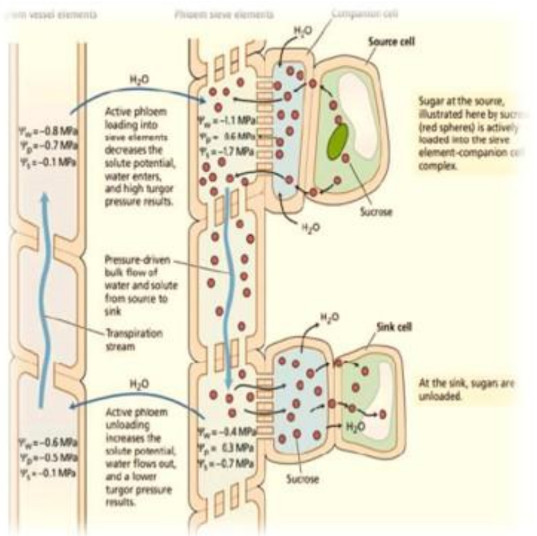


A source is any plant organ that produces more assimilates than it requires for its own growth and maintenance. Mature, fully expanded green leaves are the primary sources because they perform photosynthesis and synthesize carbohydrates. Under certain conditions, stems and other green plant parts may also contribute to photosynthate production. During later stages of crop growth, stored carbohydrates in stems and leaf sheaths can act as temporary sources by supplying assimilates to developing reproductive organs, particularly under stress conditions (Fischer, 2008).

WHAT IS A SINK?

A sink is any plant organ that consumes or stores assimilates for growth, development, or reserve accumulation. Young leaves, developing grains, seeds, fruits, roots, tubers, stems and flowers function as sinks because they depend on assimilates produced elsewhere in the plant. The strength of a sink depends on its size, growth rate and ability to attract and utilize assimilates. Stronger sinks generally receive a greater share of photosynthates, contributing to higher yield and better crop quality.

ASSIMILATE TRANSLOCATION



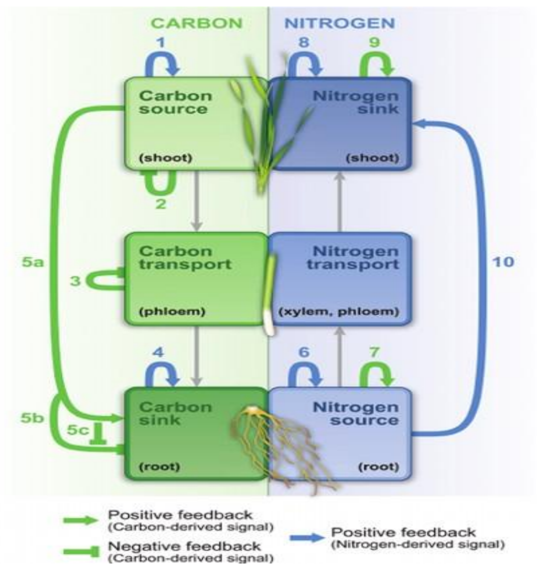
The movement of sugars from source to sink occurs through the phloem, a specialized vascular tissue responsible for transporting photoassimilates throughout the plant. After photosynthesis, sucrose is loaded into the phloem and transported to actively growing or storage organs, where it is used for respiration, cell division, tissue development and reserve formation. Efficient phloem transport ensures a continuous supply of assimilates to sink organs and supports optimum crop growth.

DYNAMIC NATURE OF SOURCE–SINK RELATIONSHIP

The source–sink relationship is not static but changes throughout the crop life cycle. During the vegetative stage, young leaves, roots and stems are the major sinks. As plants enter the reproductive stage, developing flowers, pods, grains, fruits or seeds become the dominant sinks and demand a large proportion of the assimilates. Therefore, maintaining healthy source leaves and enhancing sink strength during reproductive growth are essential for achieving higher yields.

The efficiency of the source–sink relationship is influenced by several factors, including genotype, nutrient availability, irrigation, temperature, solar radiation, plant density, hormonal balance and biotic and abiotic stresses. Proper crop management practices help maintain an optimum balance between source activity and sink demand, leading to efficient assimilate partitioning, improved resource-use efficiency and enhanced crop productivity (Reynolds *et al.,* 2021).

SOURCE: SINK RELATIONSHIP ON CARBON AND NITROGEN



Source tissues are net exporters of a resource required for plant growth, such as carbon and nitrogen, while sink tissues are net importers and are responsible for resource assimilation. Mature leaves are net sources of carbon but sinks for nitrogen, while root tissues are net sources of nitrogen but sinks for carbon. Cells require carbon and nitrogen for growth and development; nitrogen to maintain protein turnover and carbon for respiration to fuel metabolic processes. Other elements are also vital for growth, such as oxygen obtained from the air, hydrogen from water and minerals found in soil including the macronutrients (P, K) and numerous micronutrients.

CO_2 from the atmosphere is fixed by plants in the process of photosynthesis, to generate triose phosphate which is converted to sucrose, which is a readily available store of carbon, or starch, for longer-term storage. The amount of starch stored in leaves varies between different species; many temperate grass species also use the polymer fructan for long-term carbon storage. Once nitrogen assimilated into amino acids, can be stored as protein for long-term storage or amino acids for readily available nitrogen to be combined with carbon fixed in photosynthesis. The ratio of free amino acids to sucrose expresses the relative availability of nitrogen and carbon. With a high ratio indicating an excess of available nitrogen and a low ratio indicating an excess of available carbon.

DRY MATTER PARTITIONING IS DECIDED BY SOURCE STRENGTH AND SINK STRENGTH

Source Strength and Sink Strength

The efficiency of dry matter production and its partitioning depend on the balance between **source strength** and **sink strength**.

Source Strength = Source Size × Source Activity

Source strength is determined by the amount of photosynthetically active leaf area (source size) and its photosynthetic efficiency (source activity). Greater leaf area and higher photosynthetic rate increase photoassimilate production.

Example: Leaf Area Index (LAI) × Net Assimilation Rate (NAR)

Sink Strength = Sink Size × Sink Activity

Sink strength is the capacity of plant organs to attract, utilize and store photoassimilates. Sink size refers to the storage capacity of organs, while sink activity represents their ability to utilize assimilates. In cereals, sink size is indicated by the number of panicles plant^{-1}, spikelets panicle^{-1} and 1000-grain weight. Grains, seeds, fruits, tubers and storage roots are major sink organs.

An optimum balance between source and sink strength ensures efficient dry matter partitioning and maximum crop productivity. Excess source with a weak sink may lead to assimilate accumulation and reduced photosynthesis, whereas a strong sink with a weak source limit assimilate supply, reducing growth and yield.

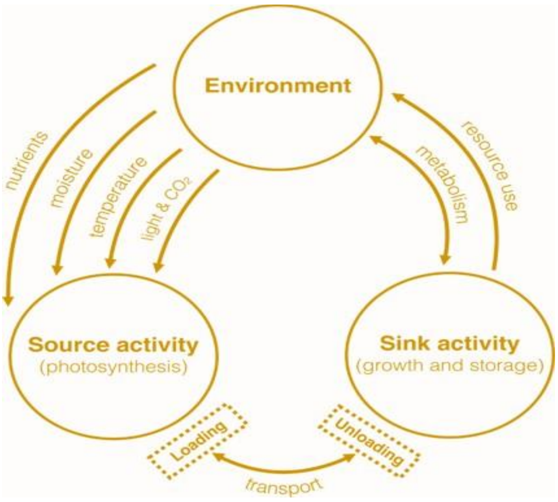
IMPACT OF SOURCE-SINK RELATIONSHIPS ON CROP GROWTH RATES AND PRODUCTIVITY

Variation in Crop Growth Rates

Source-Sink Balance: The balance between source strength and sink demand affects growth rates. Crops with a strong source but limited sink capacity may exhibit robust vegetative growth but may underperform in terms of yield. Conversely, crops with efficient sink development but limited sources may have stunted growth and reduced yield.

Environmental Influences: Environmental factors, such as light, temperature, and water availability, influence both source strength and sink efficiency. For example, adequate sunlight enhances photosynthesis, improving source capacity, while water availability impacts sink development and overall plant health.

Source-Sink Ratio: The ratio of source strength to sink demand can determine the growth rate of a plant. A high source-to-sink ratio typically supports faster growth and higher yields. Conversely, if sinks outpace sources, growth may be limited.



Resource Allocation: Efficient allocation of photosynthates from sources to sinks affects growth rates. Plants that can effectively balance this allocation tend to grow more rapidly and produce higher yields.

Optimizing Resource Allocation

Improving Source Efficiency: Enhancing photosynthetic efficiency through practices such as optimizing plant density, improving light interception, and selecting high-performing varieties can increase the number of resources available to sinks, thereby boosting productivity.

Enhancing Sink Capacity: Breeding crops with improved sink strength, such as larger or more efficient fruits and seeds, can lead to higher yields. Agronomic practices like proper irrigation and nutrient management can also support sink development.

Agronomic Practices

Fertilization and Soil Management: Adequate soil nutrients support both source strength and sink development. Balanced fertilization practices ensure that crops have the resources needed for optimal photosynthesis and reproductive growth.

Water Management: Proper irrigation practices ensure that source tissues remain productive and that sink areas receive sufficient resources. Water stress can impair both photosynthesis and resource allocation, leading to reduced growth rates and productivity.

HARVEST INDEX

Two useful terms used to describe partitioning of dry matter by the plant are biological yield & economic yield. Economic yield and agricultural yield have been used to refer to the volume or weight of those plant organs that constitute the product of economic or agricultural value. It must be remembered that the biological yield total, often does not include root weight because of the difficulty in obtaining those values.

Crop	Harvest Index (%)
Cereals	50-60
Oilseeds	45-50
Pulses	30-45
Sugarcane	35

IMPORTANCE OF SOURCE–SINK MANAGEMENT IN CROP PRODUCTIVITY

Enhances crop productivity and yield: Improves photosynthetic efficiency, assimilate production, translocation and dry matter partitioning to economically important plant parts such as grains, seeds, fruits, tubers and roots, resulting in better grain filling and higher yield.

Improves crop quality and resource-use efficiency: Enhances seed size, fruit quality, oil, starch and protein accumulation while increasing the efficient use of water, nutrients and solar radiation, thereby supporting sustainable agricultural production.

Increases stress tolerance and sustainability: Maintains source activity and sink strength under drought, heat, salinity and nutrient stress, reducing yield losses and ensuring stable productivity under changing climatic conditions.

Supports climate-resilient agriculture and food security: Optimizes the source–sink balance through improved crop management and breeding approaches, leading to higher productivity, better resource conservation and long-term food and nutritional security.

Examples of Source–Sink Management in Major Crops

Crop group	Important source–sink management practices
Cereals	Timely sowing, balanced fertilization, optimum irrigation and delayed leaf senescence improve grain filling and yield.
Pulses	Foliar nutrients, plant growth regulators, biostimulants and irrigation during flowering and pod development enhance pod retention and seed filling.
Oilseeds	Balanced nutrient management, moisture conservation and healthy foliage improve seed development, oil accumulation and productivity.
Horticultural crops	Pruning, canopy management, fruit thinning and balanced fertilization improve fruit size, quality, sweetness and market value.

CONCLUSION

Source–sink management is an effective strategy for enhancing crop productivity by improving the production, transport and utilization of photoassimilates. Maintaining a balance between source activity and sink demand through proper agronomic practices, efficient resource management and improved crop varieties enhances yield, quality and stress tolerance. As climate change and resource limitations continue to challenge agriculture, adopting source–sink management strategies will be essential for achieving sustainable and resilient crop production while ensuring long-term food security.

REFERENCES

Fischer, R. A. (2008). The importance of grain or kernel number in wheat: A reply to Sinclair and Jamieson. *Field Crops Research, **105***(1–2), 15–21. https://doi.org/10.1016/j.fcr.2007.04.002

Marcelis, L. F. M., Heuvelink, E. and Goudriaan, J. (1998). Modelling biomass production and yield of horticultural crops: A review. *Scientia Horticulturae, **74***(1–2), 83–111. https://doi.org/10.1016/S0304-4238(98)00083-1

Reynolds, M. P., Braun, H. J., Cavalieri, A. J., Chapotin, S. M., Davies, W. J., Ellul, P. and Langridge, P. (2021). Improving global integration of crop research. *Science, **372***(6543), 676–677. https://doi.org/10.1126/science.abi5551

Taiz, L., Zeiger, E., Møller, I. M. and Murphy, A. (2018). *Plant physiology and development* (6th ed.). Sinauer Associates/Oxford University Press.

Wardlaw, I. F. (1990). *The control of carbon partitioning in plants*. New Phytologist, 116(3), 341–381. https://doi.org/10.1111/j.1469-8137.1990.tb00524.x

White, A. C. and Rogers, A. (2020). A framework for understanding sources of sink limitation in photosynthesis. *New Phytologist, **227***(5), 1477–1489. https://doi.org/10.1111/nph.16713.