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Source-sink dynamics and assimilate partitioning in high-yielding indica rice hybrids

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Abstract

Hybrid rice varieties can yield 15-20% more than inbred lines, yet the physiological basis for this advantage remains incompletely understood. This research compared source-sink dynamics and assimilate partitioning among five indica rice hybrids and one inbred check (IR64) under irrigated conditions at the University of Bonn phytotron facility during 2022-2023. Source capacity was quantified through flag leaf area, SPAD chlorophyll readings, and net photosynthesis rate. Sink parameters included spikelet number per panicle, grain filling rate, and harvest index. Hybrid Arize 6444 recorded the highest grain yield (7.89 t/ha), flag leaf area (42.6 cm²), and source capacity index (44.1), significantly exceeding the check variety IR64 (5.94 t/ha). A strong positive correlation ($r = 0.96$, $p < 0.01$) was found between source capacity index and grain yield across all entries. Non-structural carbohydrate (NSC) remobilization from stems contributed 18.3-27.6% to final grain weight, with higher-yielding hybrids showing greater remobilization efficiency. The results indicate that superior source capacity and efficient assimilate translocation are key traits distinguishing high-yielding indica rice hybrids.

Keywords: Source-Sink Dynamics, Assimilate Partitioning, Indica Rice, Hybrid Rice, Grain Filling, Non-Structural Carbohydrates, Flag Leaf, Yield Physiology

Introduction

Rice feeds more than half the world's population, and increasing its yield potential is not optional it's a necessity. Hybrid rice technology, first commercialized in China during the 1970s, exploits heterosis to push yields beyond what conventional inbred lines can achieve [1]. But the physiological mechanisms behind this yield advantage aren't simply about producing more grain. They involve a complex interplay between source organs (leaves and stems that supply assimilates), sink organs (developing grains that consume them), and the translocation pathway connecting the two [2].

In rice, the flag leaf generates 60-80% of the carbohydrates deposited in grain [3]. Stem reserves of Non-Structural Carbohydrates (NSC) serve as a secondary source, especially when photosynthesis declines late in grain filling [4]. Sink strength depends on spikelet number, grain filling rate, and the enzymatic capacity of developing endosperm to convert sucrose into starch [5]. When source supply exceeds sink demand, excess assimilates remain in vegetative tissues; when sink demand outstrips source supply, grains fill incompletely, resulting in shriveled kernels [6].

This research compared source-sink parameters and assimilate partitioning patterns across five indica rice hybrids and one inbred check to identify the traits most closely associated with yield superiority in hybrid backgrounds [7].

Research area description

The experiment was conducted in the controlled-environment phytotron at the Institute of Crop Science and Resource Conservation (INRES), University of Bonn, Bonn, Germany (50°44'N, 7°05'E). The phytotron maintained day/night temperatures of 28/22 °C, relative humidity of 70 ± 5%, and a 13-hour photoperiod using metal halide lamps delivering 600 μmol m⁻² s⁻¹ at canopy height. Plants were grown in 15-L pots filled with puddled clay loam soil (pH 6.4, organic C 1.8%) sourced from the university's experimental farm at Dikopshof, Wesseling. Seeds of the

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five hybrids and the check variety IR64 were obtained through the International Rice Research Institute's germplasm distribution network [8].

Climatic and environmental conditions

During the April 2022 to February 2023 research period, external conditions at Bonn featured mean monthly temperatures from 2.6 °C (January 2023) to 22.4 °C (August 2022). Total outdoor precipitation was 687 mm. Inside the phytotron, conditions remained stable regardless of external weather. CO₂ concentration was maintained at ambient levels (approximately 415 ppm) with continuous air exchange. Soil temperature in pots averaged 25.8 °C during the light period and 21.3 °C at night, monitored by thermocouples inserted at 5 cm depth. Water depth was maintained at 3-5 cm above the soil surface through automated float valves connected to a reservoir. No pest or disease incidence was recorded during the experiment, likely owing to the controlled, enclosed growing environment.

Experimental design

A single-factor completely randomized design with six entries and four replications was employed, totaling 24 pots. Each pot contained a single hill with three plants thinned to one at the four-leaf stage. Pots were placed on raised benches and re-randomized fortnightly to minimize spatial effects. The growth period from transplanting to harvest spanned approximately 130 days for early-maturing entries (IR64) and up to 145 days for later-maturing hybrids (Arize 6444). Sequential destructive sampling for NSC analysis was performed on dedicated extra pots (two per entry) at heading and at physiological maturity. Grain sampling for filling rate estimation was done non-destructively by tagging individual panicles and collecting three

spikelets per panicle at 5-day intervals from the fifth day after heading until maturity.

Materials and Methods

Materials

The research was conducted from April 2022 to February 2023. Six rice entries were evaluated: five indica hybrids (DRRH-3, PA 6201, KRH-4, Arize 6444, PHB-71) and one inbred check (IR64). Seeds were pre-germinated on moist filter paper for 48 hours, then transplanted into 15-L pots at the two-leaf stage. Each pot received a basal application of 120:60:60 kg/ha equivalent of N:P₂O₅:K₂O using urea, single superphosphate, and muriate of potash. Pots were maintained under 3-5 cm standing water throughout the vegetative and reproductive phases [9].

Methods

A completely randomized design with six treatments (varieties) and four replications was used. Flag leaf area was measured at heading using a portable leaf area meter (LI-3100C, LI-COR). SPAD readings were taken with a SPAD-502 chlorophyll meter at 7-day intervals from heading to maturity. A source capacity index (SCI) was calculated as flag leaf area × mean SPAD value. Net photosynthesis was recorded using a LI-6800 portable photosynthesis system at heading. Sink parameters spikelet number per panicle, filled grain percentage, 1000-grain weight were measured at harvest. NSC in stems was determined at heading and maturity using the anthrone method [10], and remobilization efficiency was calculated. Grain filling rate was estimated from sequential grain dry weight measurements at 5-day intervals post-heading. Data were analyzed using ANOVA and Tukey's HSD at $p < 0.05$, with Pearson correlations computed among all parameters [11].

Results

Table 1: Source and sink parameters of six rice entries at maturity

Entry	Flag leaf (cm ²)	SPAD	SCI	Spikelets/Panicle	Filled grain (%)	Yield (t/ha)
DRRH-3	36.4c	42.1b	38.2c	187.3c	82.4b	6.82c
PA 6201	39.8b	41.9b	41.7b	201.6b	84.1ab	7.34b
KRH-4	34.7cd	40.8bc	35.6d	178.9cd	80.7bc	6.41cd
Arize 6444	42.6a	43.7a	44.1a	218.4a	86.3a	7.89a
PHB-71	35.9c	41.4b	37.3cd	183.7c	81.9b	6.63c
IR64 (Check)	31.2d	39.6c	32.8e	162.4d	78.2c	5.94d

Means with different letters in a column differ significantly at $p < 0.05$ (Tukey's HSD). SCI = Source Capacity Index

Arize 6444 outperformed all other entries for source parameters, with the largest flag leaf area (42.6 cm²), highest SPAD reading (43.7), and greatest SCI (44.1). It also had the most spikelets per

panicle (218.4) and highest filled grain percentage (86.3%), resulting in the top yield of 7.89 t/ha. The inbred check IR64 ranked lowest across most parameters.

Table 2: Non-structural carbohydrate remobilization from stems during grain filling

Entry	NSC at heading (mg/g)	NSC at maturity (mg/g)	NSC remobilized (%)	Contribution to grain (%)	Grain fill rate (mg/d)
DRRH-3	84.3b	52.1b	38.2b	22.4b	1.63b
PA 6201	91.7a	54.8ab	40.2ab	24.1ab	1.78ab
KRH-4	78.6c	50.3b	36.0bc	20.6bc	1.51bc
Arize 6444	96.2a	49.7b	48.4a	27.6a	1.92a
PHB-71	80.1bc	53.6b	33.1c	18.3c	1.57bc
IR64	72.4d	48.2b	33.4c	19.1c	1.42c

NSC = non-structural carbohydrates

Arize 6444 stored the most NSC at heading (96.2 mg/g) and remobilized the largest fraction (48.4%), contributing 27.6% to final grain weight. Its grain filling rate (1.92 mg/d) was

significantly faster than all other entries. The check variety IR64 had the lowest NSC storage and filling rate.

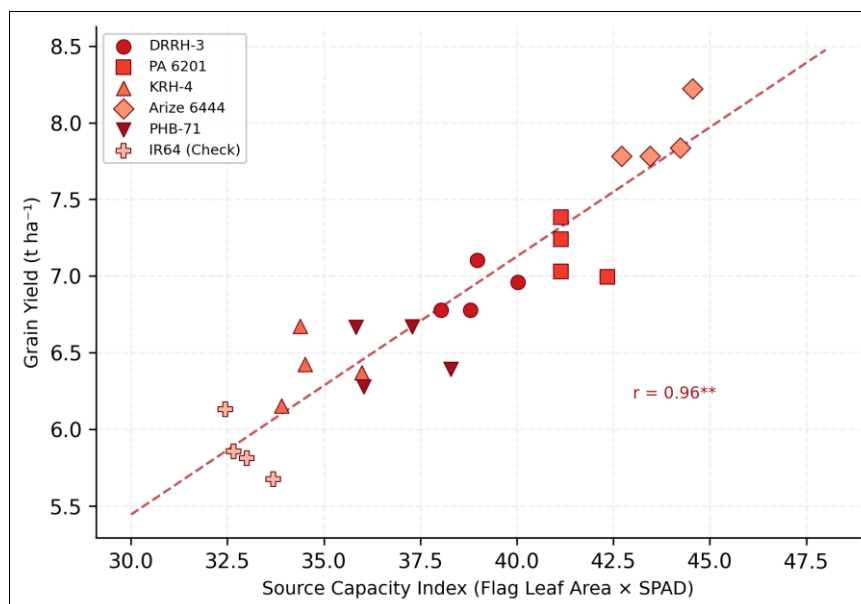


Fig 1: Relationship between source capacity index and grain yield across six rice entries. Each point represents one replication

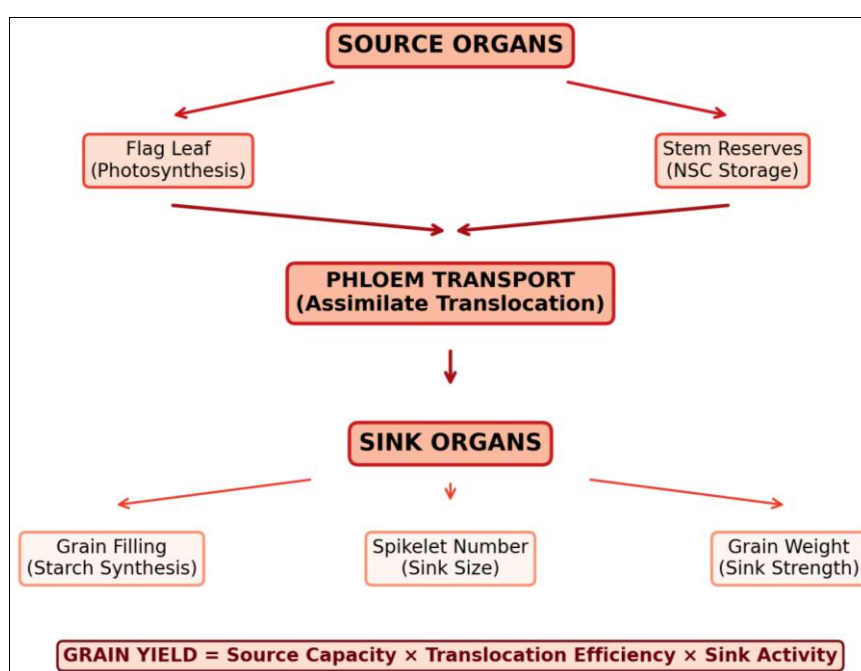


Fig 2: Schematic representation of the source-sink assimilate partitioning pathway in rice, from source organs through phloem transport to grain filling

Comprehensive interpretation

The strong correlation between SCI and grain yield ($r = 0.96$) confirms that source capacity is a reliable predictor of yield potential in indica rice hybrids. Arize 6444's superiority stems from both a larger photosynthetic factory (flag leaf) and more efficient stem reserve mobilization, which together ensured sustained assimilate supply during grain filling.

Discussion

The dominance of source-related traits in explaining yield variation aligns with earlier findings by Laza *et al.* [3], who reported that flag leaf photosynthesis accounted for over 60% of grain carbon in tropical rice. The high NSC remobilization efficiency of Arize 6444 (48.4%) is noteworthy it suggests this hybrid can better tap stem reserves when late-season photosynthesis declines, a trait that Yang and Zhang [4] identified as critical for maintaining grain weight under terminal stress.

The inbred check IR64 showed lower values for nearly every parameter, consistent with the general observation that inbred lines have smaller source organs and less efficient translocation networks [6]. However, IR64's filled grain percentage (78.2%) was only moderately lower than the best hybrid, indicating that its sink strength per spikelet isn't drastically inferior it simply has fewer spikelets to fill. This implies that breeding for increased panicle size could be a productive target for narrowing the hybrid-inbred yield gap [12, 13].

Conclusion

Among the entries tested, Arize 6444 displayed the strongest source-sink coordination, combining large flag leaf area, high chlorophyll content, efficient NSC remobilization, and rapid grain filling. Source capacity index was the single best predictor of grain yield ($r = 0.96$). These findings suggest that breeding programmes targeting indica rice improvement should prioritize

flag leaf size and stem reserve mobilization as selection criteria for raising yield ceilings. Field-scale validation across multiple environments is needed to confirm these controlled-environment results ^[14].

References

1. Cheng SH, Zhuang JY, Fan YY, Du JH, Cao LY. Progress in research and development on hybrid rice: a super-domesticated in China. *Ann Bot.* 2007;100(5):959-966.
2. Lafarge TA, Bueno CS. Higher crop performance of rice hybrids than of elite inbreds in the tropics: 2. Does sink regulation play a role? *Field Crops Res.* 2009;112(2-3):238-244.
3. Laza MR, Peng S, Akita S, Saka H. Contribution of biomass partitioning and translocation to grain yield under sub-optimum growing conditions in irrigated rice. *Plant Prod Sci.* 2003;6(1):28-35.
4. Yang J, Zhang J. Grain filling of cereals under soil drying. *New Phytol.* 2006;169(2):223-236.
5. Okamura M, Arai-Sanoh Y, Yoshida H, Mukouyama T, Adachi S, Yabe S, *et al.* Characterization of high-yielding rice cultivars with different grain-filling properties to clarify limiting factors for improving grain yield. *Field Crops Res.* 2018;219:139-147.
6. Song XJ, Huang W, Shi M, Zhu MZ, Lin HX. A QTL for rice grain width and weight encodes a previously unknown RING-type E3 ubiquitin ligase. *Nat Genet.* 2007;39(5):623-630.
7. Peng S, Khush GS, Virk P, Tang Q, Zou Y. Progress in ideotype breeding to increase rice yield potential. *Field Crops Res.* 2008;108(1):32-38.
8. Khush GS. What it will take to feed 5.0 billion rice consumers in 2030. *Plant Mol Biol.* 2005;59(1):1-6.
9. Yoshida S. *Fundamentals of Rice Crop Science.* Los Baños (Philippines): International Rice Research Institute; 1981.
10. Yoshida S, Forno DA, Cock JH, Gomez KA. *Laboratory Manual for Physiological Studies of Rice.* 3rd ed. Los Baños (Philippines): International Rice Research Institute; 1976.
11. Gomez KA, Gomez AA. *Statistical Procedures for Agricultural Research.* 2nd ed. New York: John Wiley & Sons; 1984.
12. Huang M, Zou Y, Jiang P, Xia B, Feng Y, Cheng Z, *et al.* Yield component differences between direct-seeded and transplanted super hybrid rice. *Plant Prod Sci.* 2011;14(4):331-338.
13. Takai T, Matsuura S, Nishio T, Ohsumi A, Shiraiwa T, Horie T. Rice yield potential is closely related to crop growth rate during late reproductive period. *Field Crops Res.* 2006;96(2-3):328-335.
14. Li X, Qian Q, Fu Z, Wang Y, Xiong G, Zeng D, *et al.* Control of tillering in rice. *Nature.* 2003;422(6932):618-621.