Dense planting enhances grain yield and profitability in low-yielding paddy fields of Sub-Saharan Africa

Rice yields in Sub-Saharan Africa (SSA) average 2.1 t ha^{-1}, which is significantly lower than in other regions. Many smallholder farmers in SSA face economic constraints that limit their access to essential resources for improving yields, such as irrigation facilities, chemical fertilizers, and high-quality seeds. Optimizing planting density is a technique that smallholder farmers can implement on their own without these external inputs.

The effects of planting density have been extensively studied in irrigated rice fields with relatively high yield levels exceeding 5 t ha^{-1}. However, no experimental studies have systematically examined how variations in planting density impact rice yields in low-yielding paddy fields (<5 t ha^{-1}) commonly found in SSA.

This study was conducted in Madagascar, where low-yielding paddy fields are widespread. We examined the effects of two planting density treatments: the standard planting density of 25–26.7 hills m^{-2} (*Standard*) and a doubled density of 50–53.3 hills m^{-2} (*Dense*) using a common variety (X265) in a range of 38 environmental conditions. Additionally, based on household surveys of 356 farmers across 60 villages, we estimated the economic benefits of optimizing planting density by calculating the costs associated with seeds and labor, as well as the revenue gains from increased yields.

The results demonstrated that the dense planting had significantly and consistently higher yields than standard planting by 0.4 t ha^{-1} in the yield range of 1.8 and 4.6 t ha^{-1} while no advantage was detected when the yield was high at 5.5 t ha^{-1} or extremely low at < 1.3 t ha^{-1} (Fig. 1). In the yield range of 1.8 and 4.6 t ha^{-1}, dense planting boosted initial light interception (Fig. 2), and the cumulative light interception from transplanting to maturity was closely correlated with the grain yield (Fig. 3). A household survey identified that the added seed and labor costs for doubling transplanting density from *Standard* to *Dense* were 58,000–62,000 MGA ha^{-1} and 66,000–71,000 MGA ha^{-1}, respectively (Table 1). The additional benefit from the yield gain of 0.4 t ha^{-1} was estimated at 441,000 MGA ha^{-1}, which exceeded 3 times the sum of added seed and labor costs for doubling planting densities. The study provided a practical and impactful strategy for increasing rice yields of smallholder farmers in SSA.

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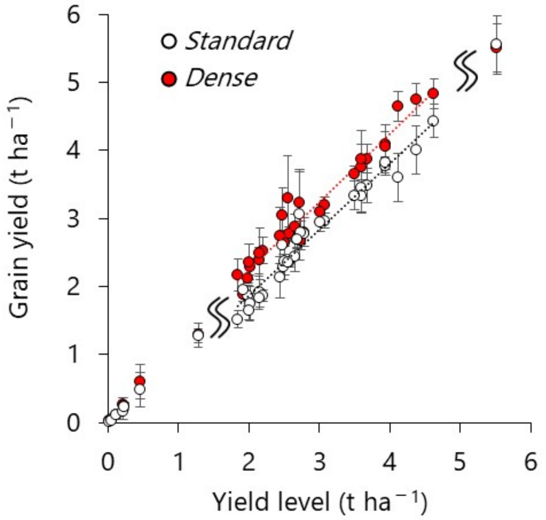

Fig. 1. Effect of transplanting density on grain yield under a range of yield levels

The yield level is the mean yield of two transplanting density treatments. The effect of transplanting density is significant with no interaction of environments in the yield range of 1.8 and 4.6 t ha^{-1} (n=30), but not significant in the other environments (n=8). Errors bars represent the standard error of the replicates.

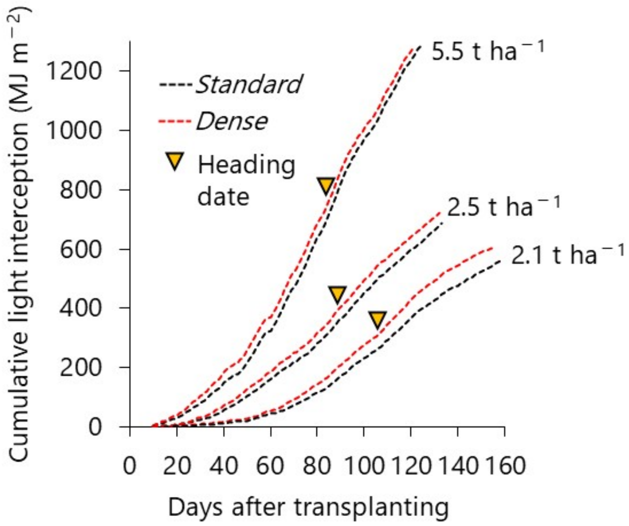

Fig. 2. Cumulative light interception at different yield levels

Cumulative light interception was determined by summing the daily intercepted radiation, which was calculated as the product of daily canopy coverage and solar radiation. The daily canopy coverage was estimated using weekly captured canopy images and the image analysis software ImageJ.

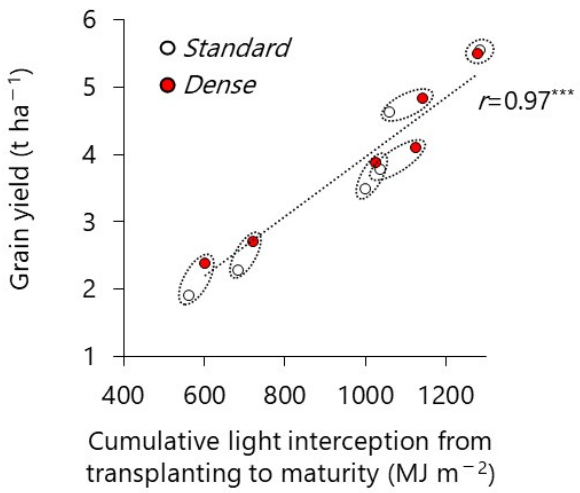

Fig. 3. Correlation between cumulative light interception and grain yield

*** Significant at p<0.001.

Table 1. Estimated costs of seeds and transplanting labor for the standard and dense planting treatments

	seed cost (10^{3}MGA ha^{-1})	labor cost for transplanting (10^{3}MGA ha^{-1})
Farmer*	106	120
Standard	58~62	66~71
Dense	116~124	132~142

*Mean of 356 farmers across 3 years. The costs of seeds and transplanting labor were estimated for the standard and dense planting treatments assuming that these costs increase or decrease in direct proportion to planting density. The average planting density of farmers was 45.2 hills m^{-2}.

Reference: Andrianary et al. (2024) *Field Crops Res.* 318: 109601.