Localized phosphorus application via P-dipping is most effective in increasing lowland rice yields when combined with seedlings at 4.5~6.5 leaf age

P-dipping refers to the placement of phosphorus (P) fertilizer at the root system during transplanting of rice by adhering P-enriched slurry to the seedling roots. This approach is beneficial for smallholder farmers in sub-Saharan Africa who apply small amounts of P to highly P-fixing soils. This study aimed to identify the optimum seedling age for maximizing the impact of P-dipping. Pot experiments revealed that the adhered amounts of slurry to the roots with P-dipping increased in a sigmoidal pattern against seedling age along with the increases in the root mass (Fig. 1). Correspondingly, the effect of P-dipping on the initial biomass was enlarged with older seedlings in a sigmoidal pattern, increasing slowly during the young seedling age (<4.5 leaves), sharply during the intermediate seedling age, and plateauing during the old seedling age (>6.5 leaves) (Fig. 2). Combining P-dipping with much older seedlings at 8 leaves resulted in severe transplanting shock and plant death.

On-farm trials on 90 fields demonstrated a significant interaction between seedling age and P treatment on grain yield under a range of growing conditions in the central highlands of Madagascar. The highest yield gains over the control from P-dipping were observed in seedlings with intermediate age (4.5~6.5 leaves), followed by old (>6.5 leaves) and young (<4.5 leaves) seedlings at 1.0 t ha^{-1}, 0.7 t ha^{-1}, and 0.6 t ha^{-1}, respectively (Table 1). These results suggested that vigorous and intermediate seedlings with higher slurry adherence than young seedlings and a lower risk of transplanting shock than old seedlings benefited most from P-dipping (Fig. 3). This finding provides smallholder farmers with practical knowledge on how to apply P-dipping more efficiently for achieving improved P management for sustainable rice production. It should be noted that the optimal seedling status and root development for P-dipping can be affected not only by the leaf age but also by the growth conditions in the nursery bed, e.g., sowing density, temperature, water management, light intensity, soil fertility, fertilizer management, and varieties.

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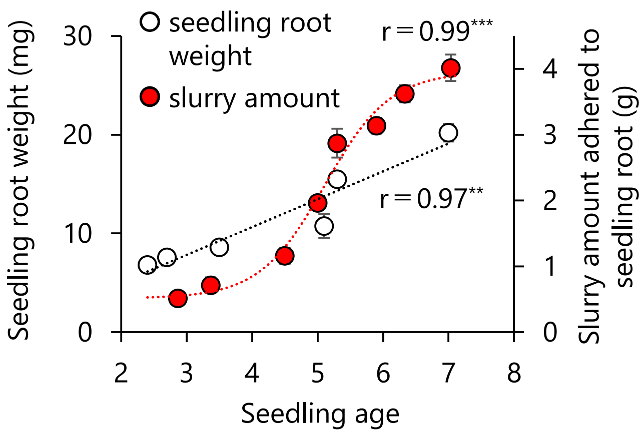

Fig. 1. Relationship between seedling age and (A) root weight and (B) slurry amount adhered to root

Seedlings were raised in a growth chamber at 25°C /15°C day/night temperature and at 20,000 lx.

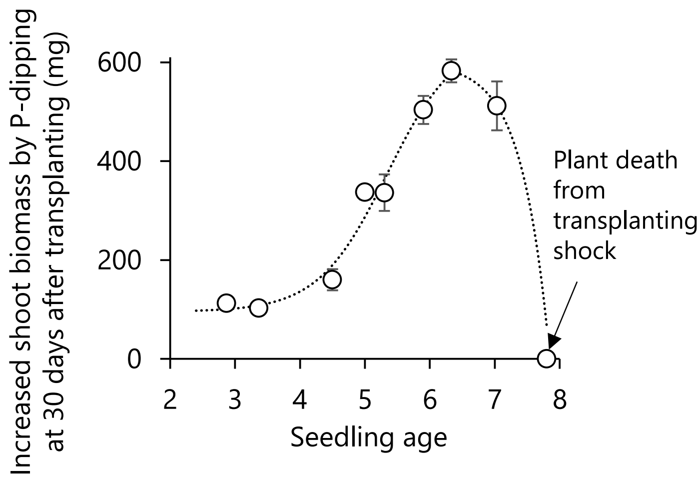

Fig. 2. Effect of P-dipping on initial biomass production using different seeding age

Plants were grown in a growth chamber at 25°C/15°C day/night temperature and at 20,000 lx.

Table 1. Variations in P-dipping effect among farmers' fields using different seedling age in Madagascar

Seedling age at transplant	Number of days in nursery (standard deviation)	Number of farmer fields	P-dipping	Grain yield (t ha^{-1})	Yield gain by P-dipping (t ha^{-1})
< 4.5	26 (6)	36	No	2.9 b	-
			Yes	3.5 a	0.6 b
4.5~6.5	47 (6)	37	No	3.0 b	-
			Yes	4.0 a	1.0 a†
> 6.5	58 (7)	17	No	2.3 c	-
			Yes	3.0 b	0.7 ab†

Means with different alphabets indicate significant differences by Tukey's HSD test. †*P*=0.09.

Apart from the P treatments, farmers used their own preferred varieties and management practices in the establishment of seedlings and transplanting patterns.

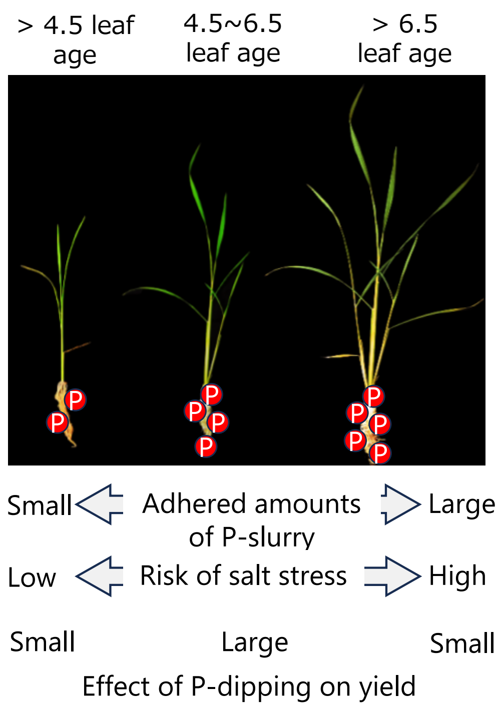

Fig. 3. Diagram on the interaction of P-dipping and seedling age

Reference: Rakotoarisoa et al. (2023) *Crop and Environment* 2: 202-208.