Efficient phosphorus application strategy to improve rice yields under cold stress-prone and P-deficient environments

Despite a general perception that phosphorus (P) deficiency delays phenological development in annual crops, the impacts of interaction between this phenological delay and climatic conditions on crop productivity remain poorly understood. On-farm experiments were conducted in the central highlands of Madagascar, where P deficiency and late-season low temperature stress frequently restrict rice yields. Rice X265 was grown under four different fertilizer treatments with different combinations of N and P during early and late transplanting dates (ETP and LTP, respectively). Plants subjected to no fertilizer or single N treatments (-P) showed delayed heading by 9–16 days relative to the single P and N and P combined plots on average (Table 1). The delay in phenological development without P application (-P) and the delay in transplanting date (LTP) additively increased the risk of low temperature stresses at the heading periods (Fig. 1). As a result, -P plots at LTP increased the cooling degree days and spikelet sterility while the delay in phenological development without P application little affected the cooling degree days and spikelet sterility when transplanted early or ETP (Fig. 2). With this significant interaction between P application and transplanting dates on cold stresses, the effect of P on rice yield was much greater in LTP than in ETP because P application alleviated not only P deficiency but low temperature stress as well by shortening day to heading (Table 1). This study provides field evidence that the effects of P application on rice yield were greatly dependent on transplanting date via their impact on phenological development under P-deficiency in climate stress-prone environments. Changes in phenological development due to plant nutrient status and its interaction with climate-induced stress needs further attention for improving fertilizer management practice.

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Table 1. Effect of P application and transplanting date on days to heading and yield of rice grown on P-deficient fields

		Days from transplanting to heading			Yield (t ha^{-1})		
		-P	+P	Difference between +P and -P	-P	+P	Difference between +P and -P
ETP	Field1	111	95	<u>-16</u>	2.2	3.1	<u>0.8</u>
	Field2	110	98	<u>-11</u>	2.4	3.2	<u>0.8</u>
LTP	Field1	109	96	<u>-12</u>	1.9	3.1	<u>1.2</u>
	Field2	105	96	<u>-9</u>	1.8	3.1	<u>1.3</u>

-P indicates the means of the plots without fertilizer and with N applied as urea at the rate of 80 kg N ha^{-1}. +P indicates the means of plots with P applied as triple super phosphate at the rate of 50 kg P_2O_5 ha^{-1} and with N and P combined.

ETP refers to early transplanting plots (November 28-29). LTP refers to late transplanting plots (December 27-30).

Underlined values indicate significant differences between -P and +P plots at 5% by Tukey HSD.

ANOVA detected a significant interaction between P treatment and transplanting dates on yield.

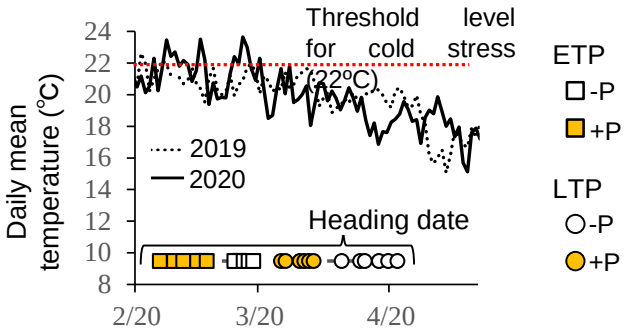

Fig. 1. Changes in daily mean temperatures at the heading periods as affected by transplanting dates and P application

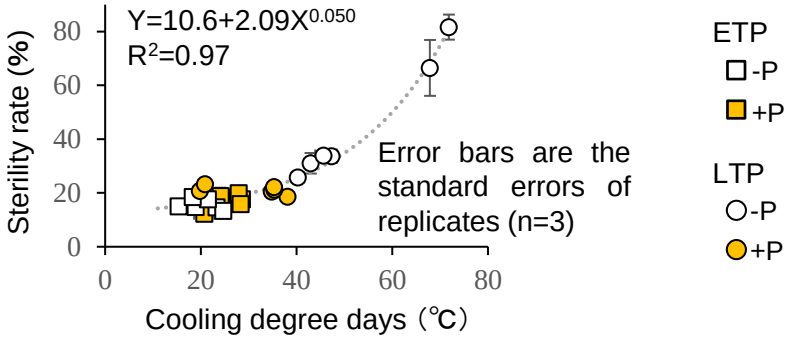

Fig. 2. Effect of transplanting dates and P application on the cooling degree days (CDD) and spikelet sterility

CDD is the sum of daily mean temperatures below 22ºC from 15 days before to 7 days after heading.

Reference: Andrianary et al. (2021) *Field Crops Research* 271: 108256, https://doi.org/10.1016/j.fcr.2021.108256, and Rakotoson et al. (2022) *Field Crops Research* 275: 108370, https://doi.org/10.1016/j.fcr.2021.108370

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