# Supporting Information for:

Advancing phosphorus foliar fertilization with nano-hydroxyapatite: mechanisms and agricultural relevance

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**Video S1**: $Z$-stack reconstruction from confocal laser scanning microscopy (CLSM), showing the distribution of fluorescent nHAp (green signal) in P-deficient barley leaves, 1 hour after application as surface droplets (see file 'Video S1.mp4'). The video was generated by sequentially displaying optical sections acquired at different depths, progressing from the top (leaf surface) to the interior (mesophyll). The same exact dataset was used to reconstruct the $zx$ cross-sectional image shown in Figure 5A.

**Video S2**: Same imaging conditions as Video S1, but with a broader field of view (see file 'Video S2.mp4').



**Fig. S1** Visual comparison of the same nHAp batch before (left) and after (right) concentration using tangential flow filtration. Both suspensions were imaged after a thorough dialysis step. ICP-MS profiles of the imaged samples are shown in Figure 2. The yellow coloration is due to doping with elemental tracers; non-doped particles display a white hue but are otherwise identical.

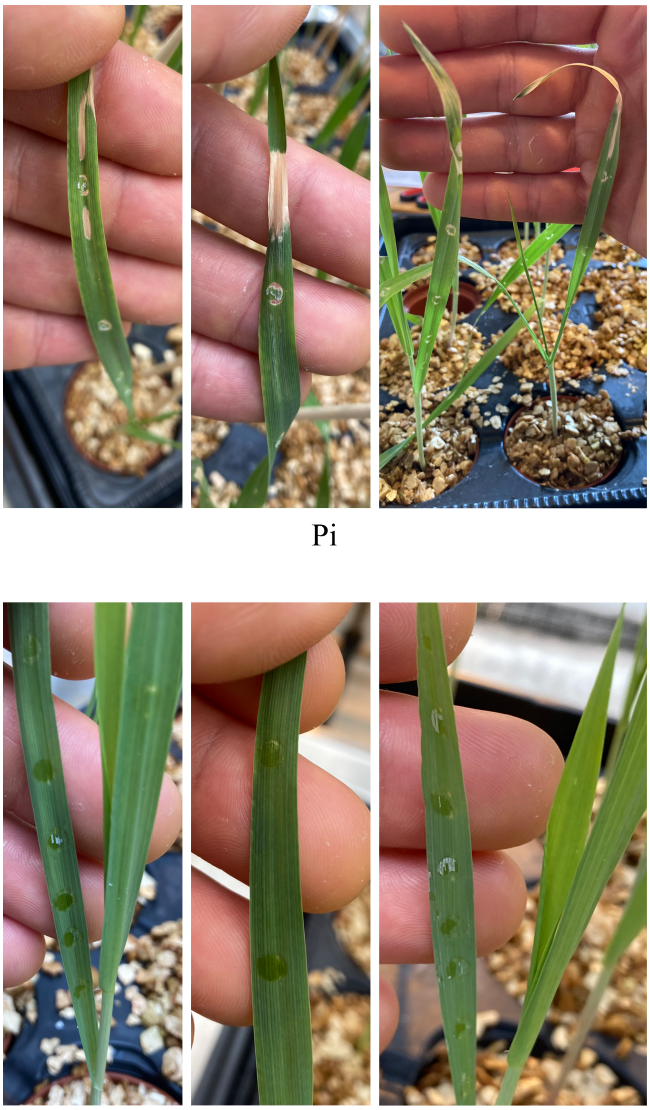



**Fig. S2** Scorching in P-deficient barley leaves 2-3 days after infiltration of $KH_2PO_4$ (Pi, top) and nHAp (bottom), both adjusted to the same P level (∼0.5 M).

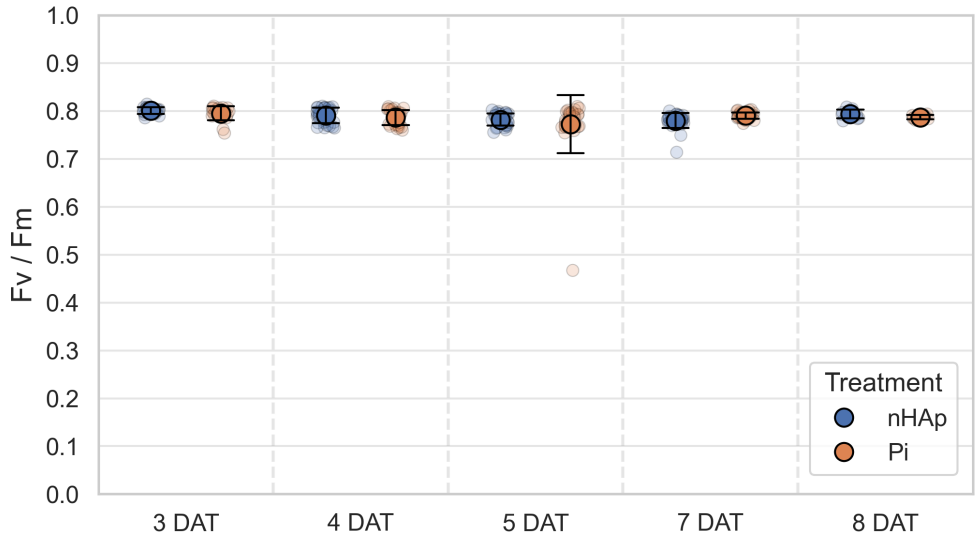



**Fig. S3** Maximum quantum yield of Photosystem II (Fv/Fm) for nHAp- and Pi-infiltrated P-deficient barley leaves over the period 3-8 days after treatment (DAT), obtained from the chlorophyll *a* fluorescence measurements reported in Figure 3. Data are presented as mean ± SD, with semi-transparent circles representing individual data points. It should be noted that Fv/Fm measurements for the Pi treatments were limited to the healthy portions of the leaves, as the extensive scorching rendered the damaged areas unmeasurable.

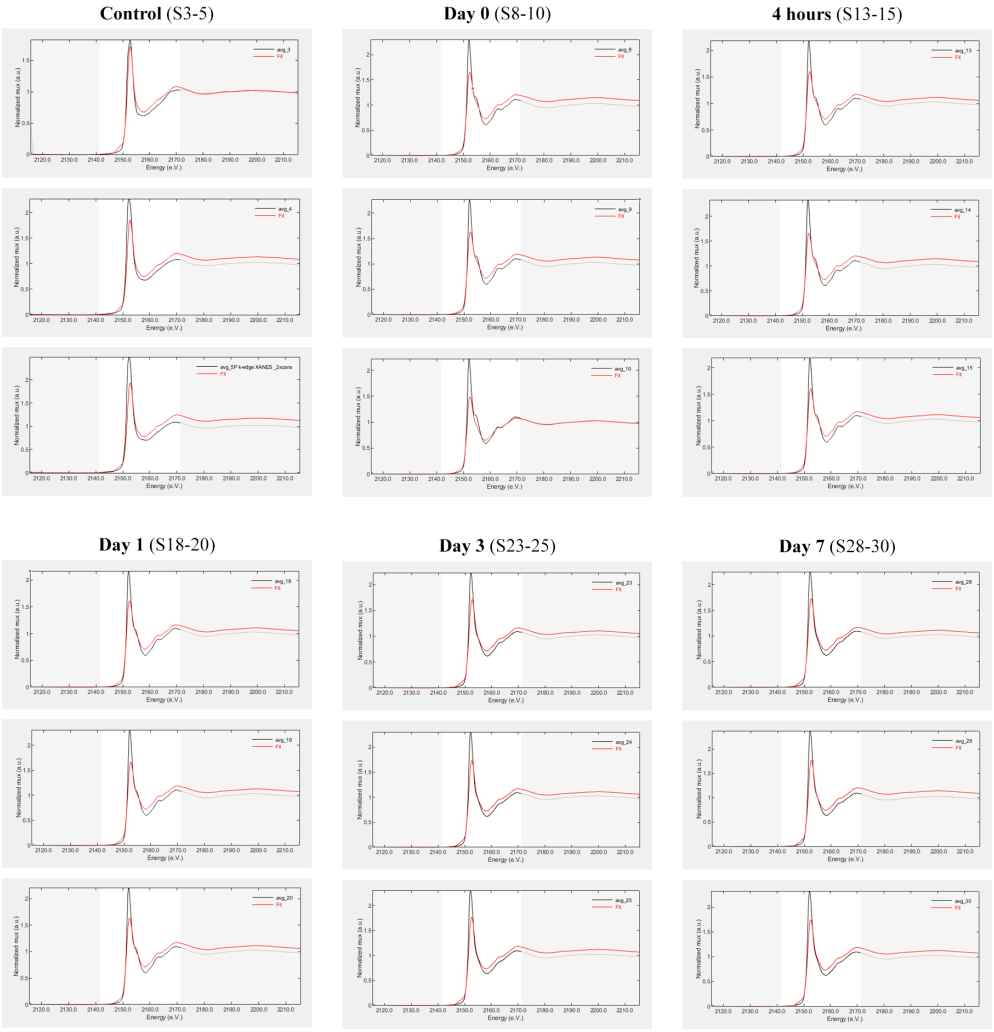



**Fig. S4** Original P K-edge XANES spectra used for the speciation analysis presented in Figure 4. Citrate treatments represent control plants infiltrated using citrate buffer, the dispersing medium for nHAp, while all other panels represent distinct harvest times after infiltration with nHAp. Replicate spectra (black) are shown together with their linear combination fits (LCF, red).

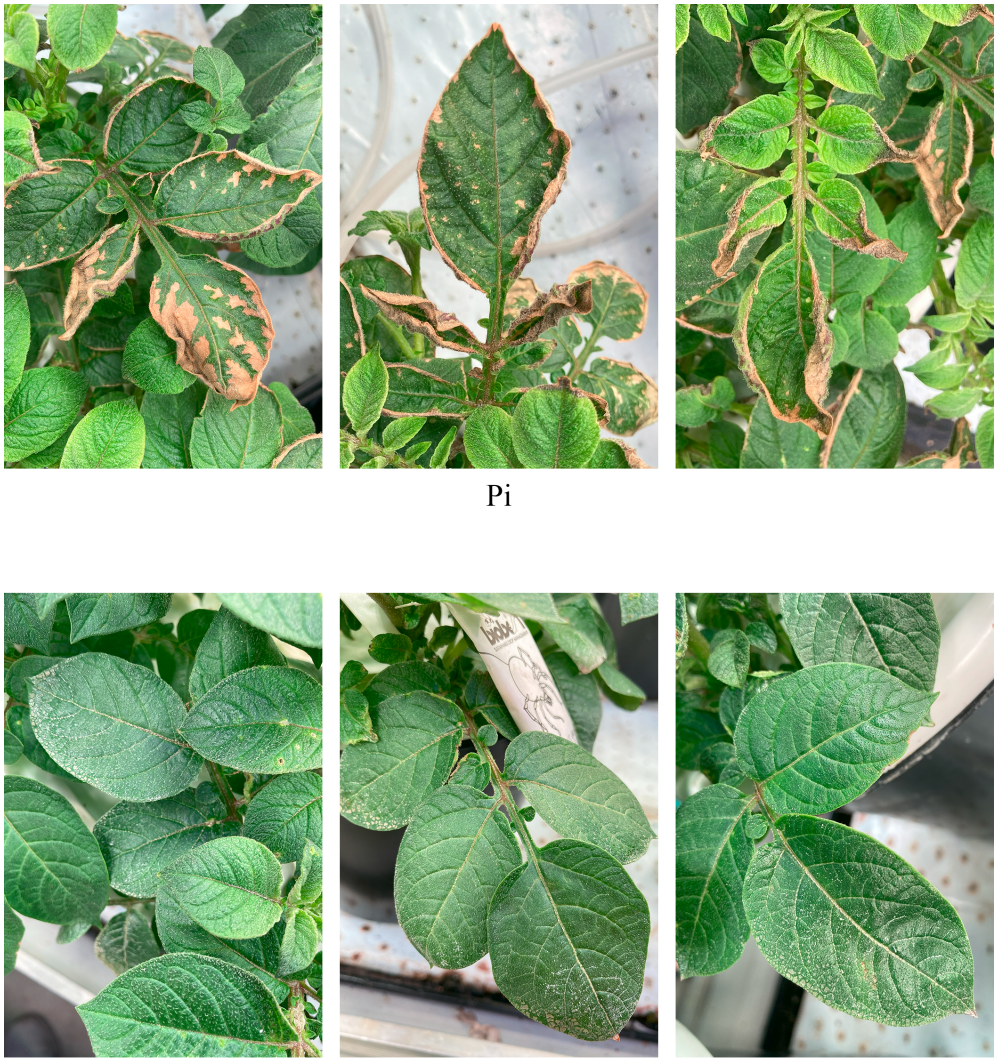



**Fig. S5** Scorching in P-deficient potato leaves a week after the application of concentrated $KH_2PO_4$ (Pi, top) and nHAp (bottom), both adjusted to the same P level (>1 M).

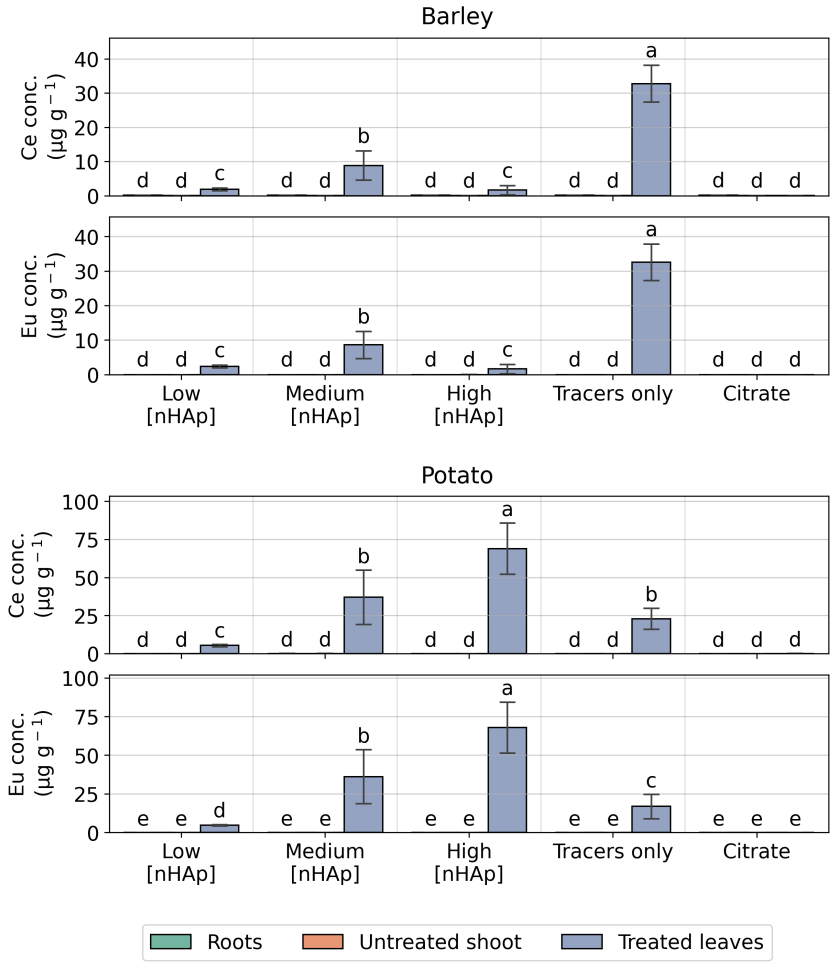



**Fig. S6** Distribution of Ce and Eu tracers in plant parts 7 days after foliar droplet application of *(i)* tracer-doped nHAp suspensions at three different concentrations, *(ii)* ionic Ce and Eu solutions ('Tracers only'), and *(iii)* citrate control buffer. Bars indicate mean tracer concentrations per leaf dry weight ± SD. Letters above bars denote statistical groups based on comparisons of all treatments within each subplot, with bars sharing at least one letter not being significantly different ($p$>0.05).

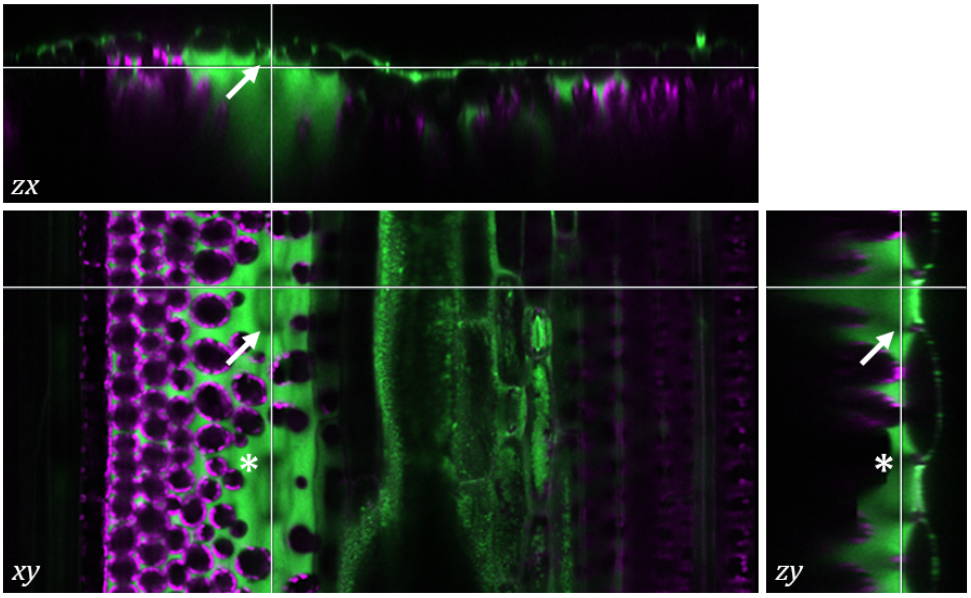



**Fig. S7** Orthogonal optical sections reconstructed from confocal laser scanning microscopy (CLSM) $z$-stack data. The central panel displays the original $xy$ plane, while the top and right panels show the corresponding $zx$ and $zy$ cross-sections. The intersection of the thin white lines marks the same spatial point across the $xy$, $zx$, and $zy$ planes, providing a reference for orientation; in this example, it is located just below the stoma, inside the sub-stomatal cavity. Arrows and asterisks indicate the same stomata, visualized from different perspectives across the three planes. The $zx$ section is the same reconstruction shown in Figure 5B.