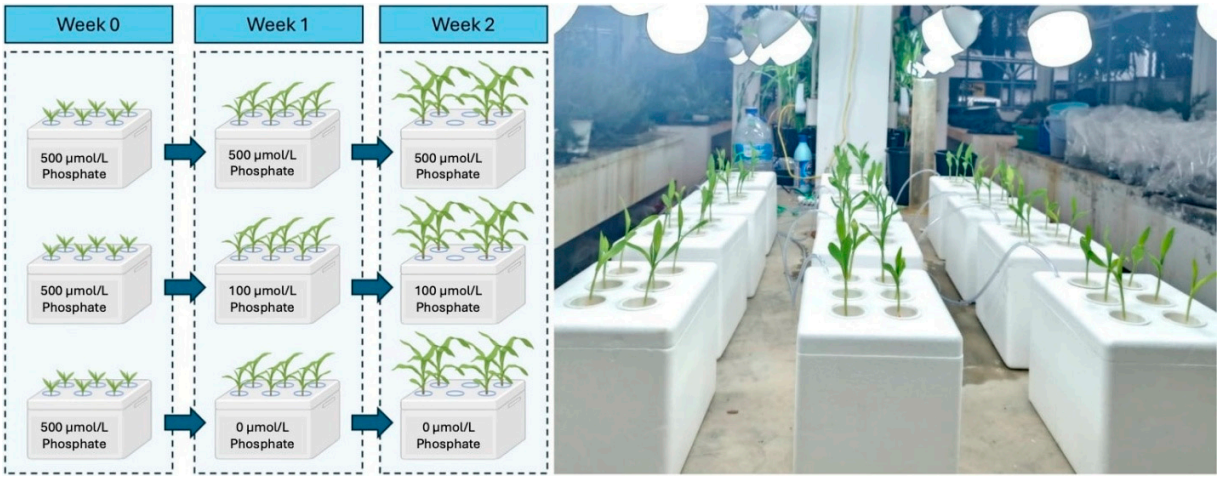
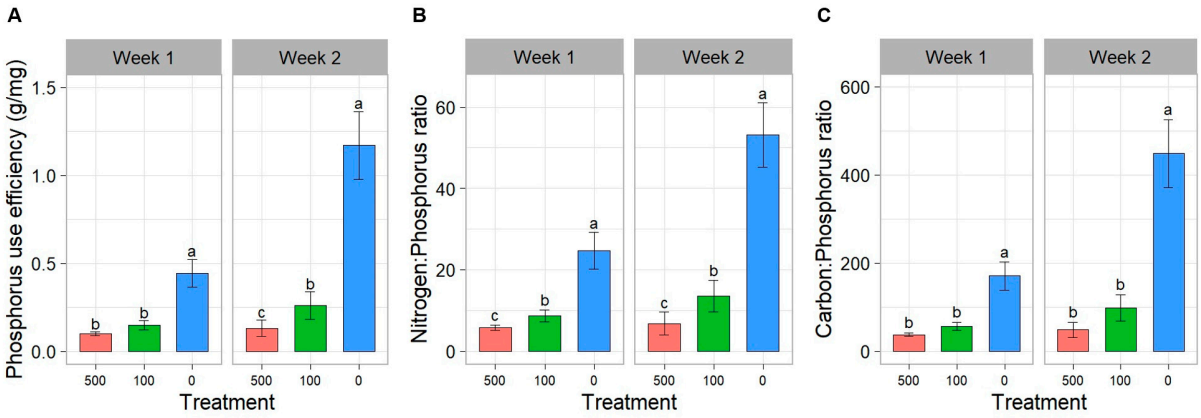
Supplementary Material



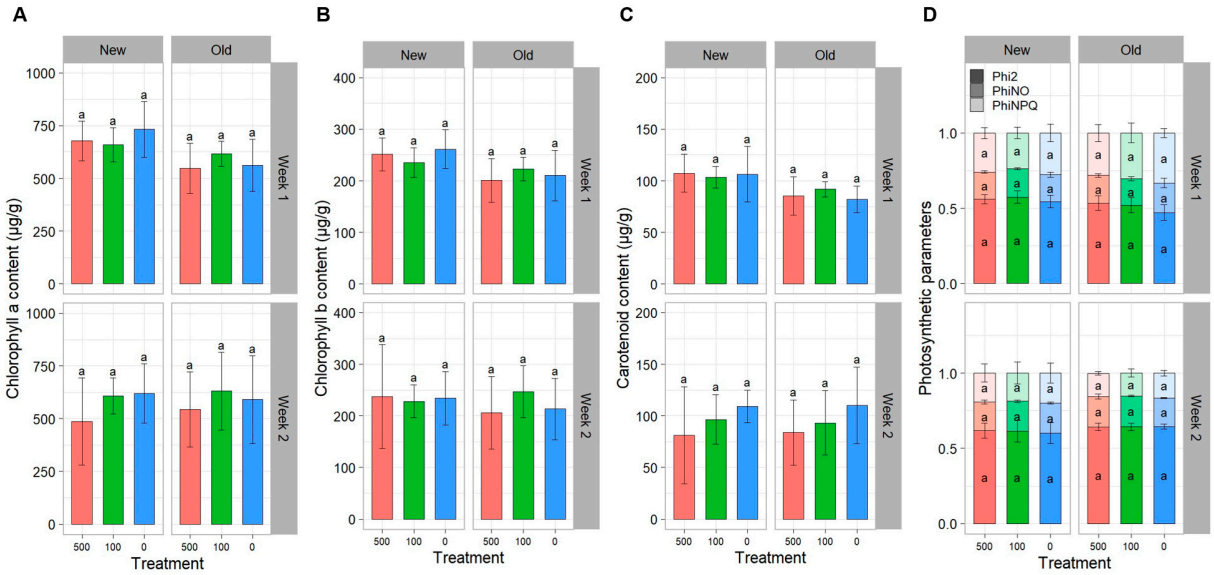
Supplementary Figure S1. Experimental design and hydroponic setup for maize seedlings grown under different phosphorus levels. The left panel (diagram) illustrates the experimental timeline: after three days of germination, maize seedlings were initially grown in 500 µmol/L Pi for one week (Week 0), followed by transfer to three Pi concentrations (500, 100, and 0 µmol/L in 0.5× Hoagland's solution) for an additional two weeks. The right panel (photograph) shows the actual hydroponic setup in the greenhouse.

Supplementary Table S1. Nutrient concentrations in maize dry biomass after six weeks of pot culture in high phosphorus (HP) and low phosphorus (LP) treatments. Nutrient analysis was performed using Inductively Coupled Plasma-Optical Emission Spectrometry. Data are presented as means ± SD (n = 14). A Student's t-test was used to compare differences between HP and LP treatments. Asterisks indicate statistically significant differences (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$), and "ns" indicates non-significant differences.

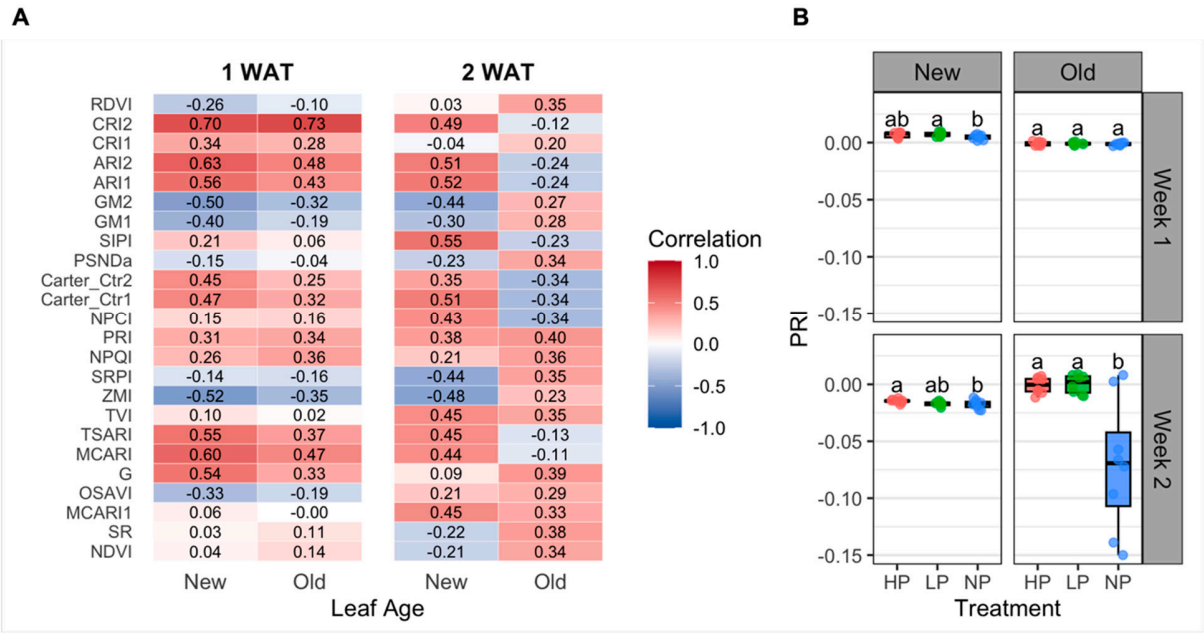
Element (mg/kg)	**Treatment**		**P-value**	**Significance**
	HP	**LP**		
C	439,563.10 ± 3,561.43	429,456.30 ± 13,473.75	0.098	ns
N	11,241.94 ± 1,820.54	18,007 ± 2,950.62	<0.001	***
P	1,097.85 ± 106.15	493.45 ± 54.57	<0.001	***
K	19,856.95 ± 1355.57	32,940.94 ± 8298.35	0.006	**
Ca	4,431.68 ± 345.77	6,170.53 ± 755.14	<0.001	***
Mg	2,812.03 ± 247.06	3,300.84 ± 382.46	0.017	*
S	1,236.17 ± 891.29	1,478.12 ± 1338.66	0.699	ns
Cu	10.48 ± 11.81	4.52 ± 0.93	0.231	ns
B	9.77 ± 1.05	11.88 ± 5.10	0.321	ns
Mo	3.39 ± 0.57	8.92 ± 0.37	<0.001	***
Mn	19.28 ± 5.56	20.62 ± 9.26	0.749	ns
Zn	14.85 ± 4.30	20.23 ± 2.96	0.02	*
Cl	1,049.12 ± 269.17	4,731.64 ± 1,991.68	0.003	**



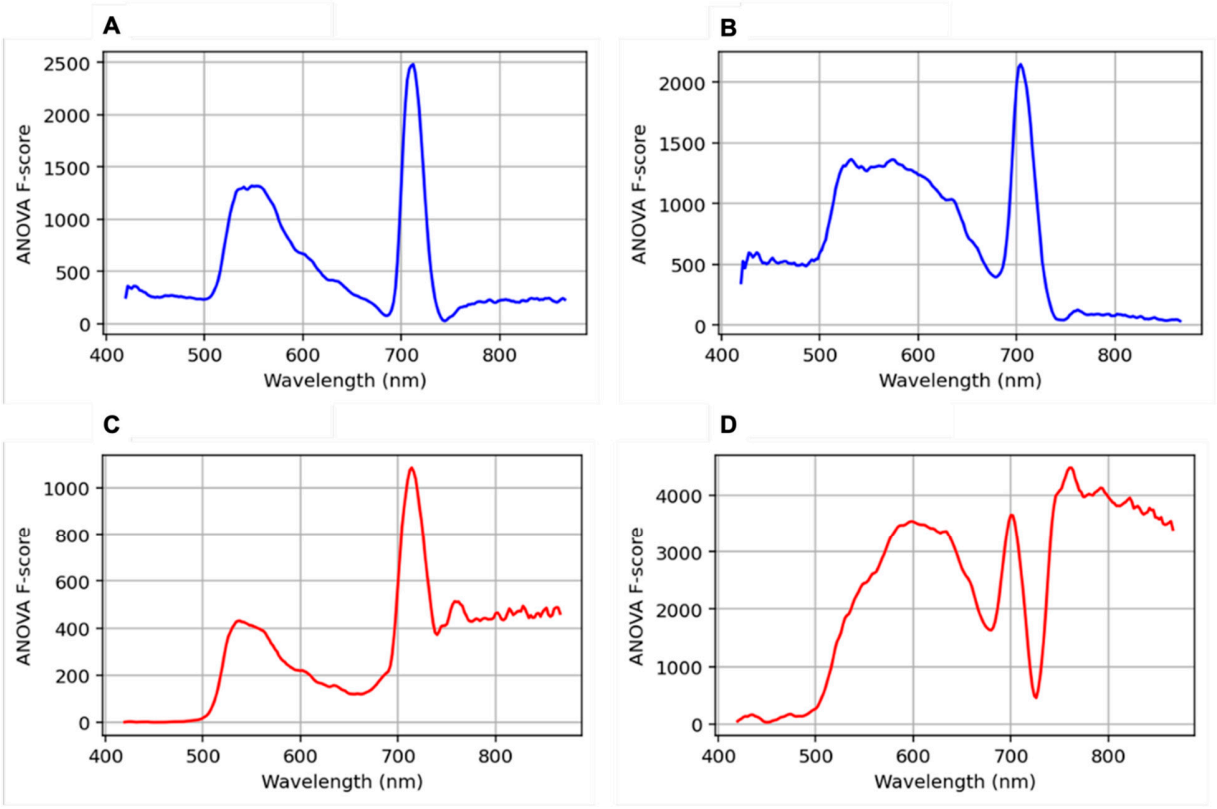
Supplementary Figure S2. Effect of phosphorus availability on phosphate use efficiency (PUE) and nutrient ratios in maize seedlings during early growth stages. Maize was grown hydroponically with three levels of phosphorus supply (500, 100, and 0 μM Pi). (**A**) Phosphate use efficiency (PUE), (**B**) Nitrogen-to-phosphorus ratio, and (**C**) carbon-to-phosphorus ratio were also affected by phosphorus availability at Week 1 and Week 2. Data are means ± SD (n = 8). Different letters above the bars indicate statistically significant differences among treatments within each week (p < 0.05).



Supplementary Figure S3. Effect of phosphorus deficiency on pigment accumulation and photosynthetic parameters in maize seedlings grown under hydroponic conditions. (**A–C)** Photosynthetic pigments: chlorophyll a, chlorophyll b, and carotenoids in Leaf 1 and Leaf 4 at Week 1 and Week 2. **(D)** Photosynthetic parameters (Phi2, PhiNPQ, and PhiNO) measured in Leaf 1 and Leaf 4. Data are means ± SD (n = 8). Significant differences between treatments were evaluated using one-way ANOVA followed by an LSD test. Different letters above the bars indicate a significant difference at $p < 0.05$.



Supplementary Figure S4. Relationships between vegetation indices and leaf phosphate (Pi) content, and treatment effects on photochemical reflectance index (PRI) in maize. Heatmaps display Pearson correlation coefficients between leaf Pi content and vegetation indices in new and old leaves at 1 and 2 weeks after treatment (WAT) (**A**). Red indicates positive correlations, and blue indicates negative correlations; color intensity reflects correlation strength. Boxplots show PRI values (n = 8) in new and old leaves at the first and second week under three P treatments (**B**): high P (HP, 500 μM Pi), low P (LP, 100 μM Pi), and no P (NP, 0 μM Pi). Different letters indicate significant differences among treatments within each leaf age and time point (LSD test, $p < 0.05$).



Supplementary Figure S5. Wavelength-specific discriminatory power for phosphorus (P) status classification. ANOVA F-score profiles across the visible and near-infrared spectrum show the statistical significance of individual wavelengths in distinguishing among high P (500 μmol/L Pi), low P (100 μmol/L Pi), and no phosphorus (0 μmol/L) treatments from new and old leaves, respectively, at the first (A-B) and second (C-D) week after treatment initiation. Higher F-scores indicate greater discriminatory power at specific wavelengths.