

Article

Optical Sensing of Nitrogen, Phosphorus and Potassium: A Spectrophotometrical Approach Towards Smart Nutrient Deployment

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Plotted solid black line represents the real concentration of the analyte and symbols represent each addition of the respective interferent and its perceived effect on the analyte concentration.

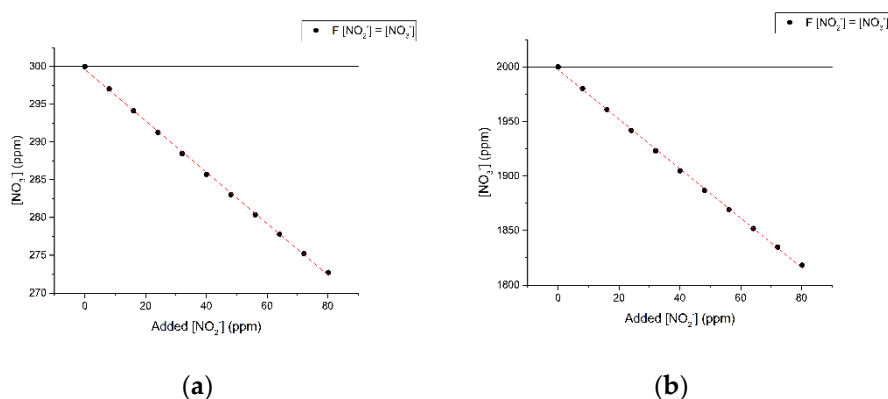


Figure 1. Tests A1 and A2: nitrite interference in a (a) low nitrate concentration sample, $[\text{NO}_3^-] = 300$ ppm; and in a (b) high concentration sample, $[\text{NO}_3^-] = 2000$ ppm. Each increment of nitrite represents ≈ 8 ppm.

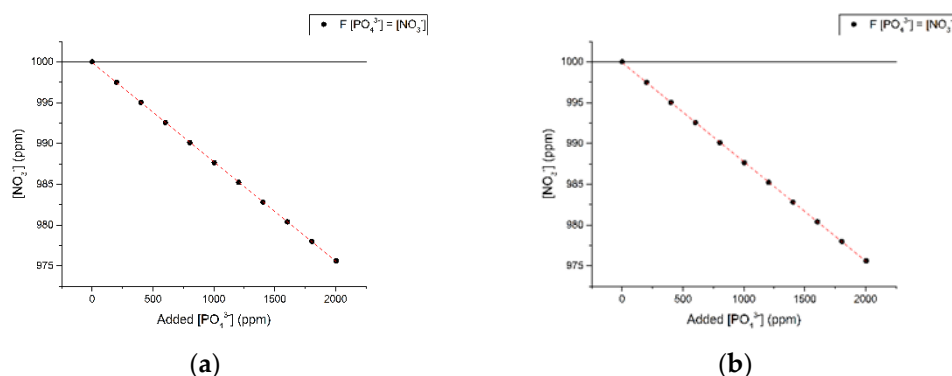


Figure 2. Tests B1 and B2: phosphate interference in a (a) nitrate sample, $[\text{NO}_3^-] = 1000$ ppm; and a (b) nitrate/nitrite sample, $[\text{NO}_3^-] = [\text{NO}_2^-] = 1000$ ppm. Each increment of PO_4^{3-} represents ≈ 200 ppm.

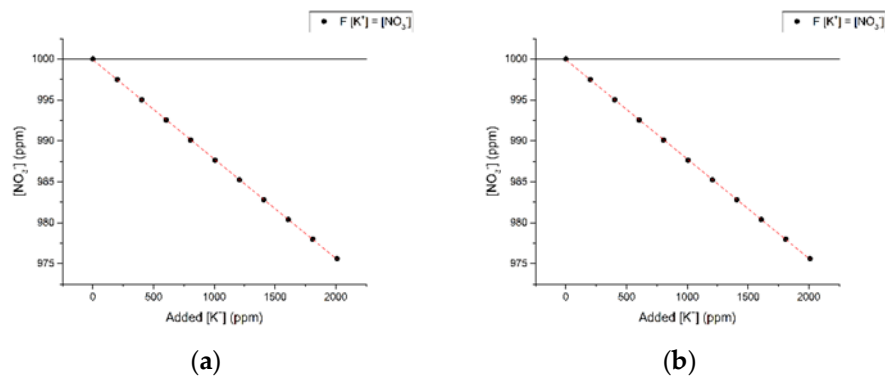


Figure 3. Tests C1 and C2: potassium interference in a (a) nitrate sample, $[\text{NO}_3^-] = 1000$ ppm; and a (b) nitrate/nitrite sample, $[\text{NO}_3^-] = [\text{NO}_2^-] = 1000$ ppm. Each increment of K^+ represents ≈ 200 ppm.

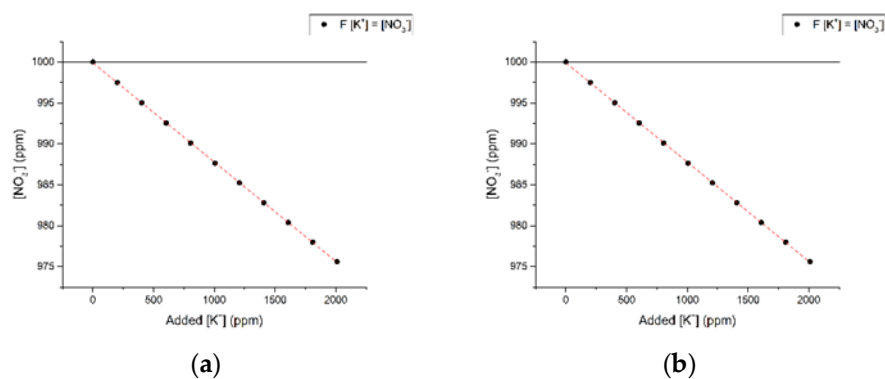


Figure 4. Tests D1 and D2: phosphate and potassium (1:1) mixture interference in a (a) nitrate sample, $[\text{NO}_3^-] = 1000$ ppm; and a (b) nitrate/nitrite sample, $[\text{NO}_3^-] = [\text{NO}_2^-] = 1000$ ppm. Each increment of $\text{PO}_4^{3-}/\text{K}^+$ mixture represents 1250–1260 ppm.

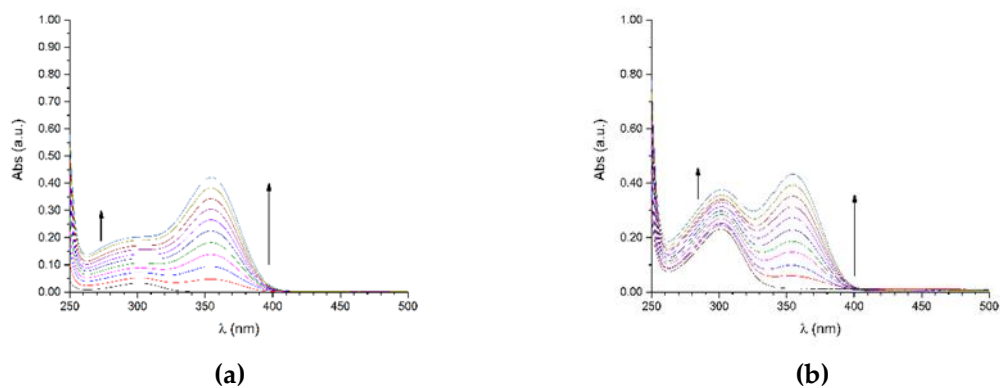


Figure 5. Acquired spectra for (a) Tests A1 and (b) Test A2.

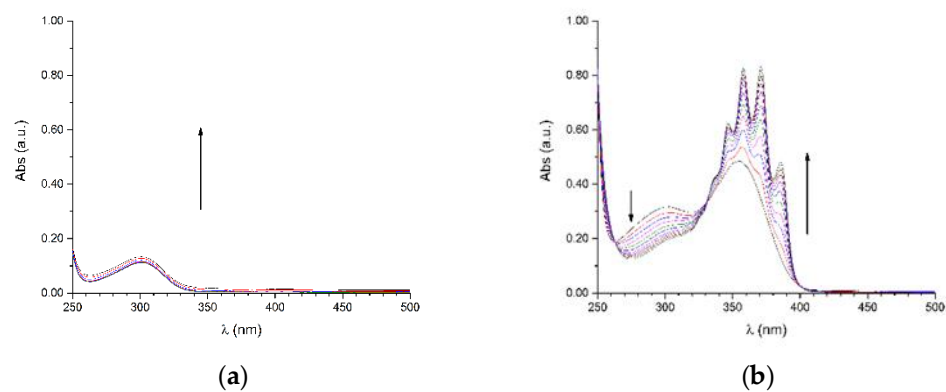


Figure S6. Acquired spectra for (a) Tests B1 and (b) Test B2.

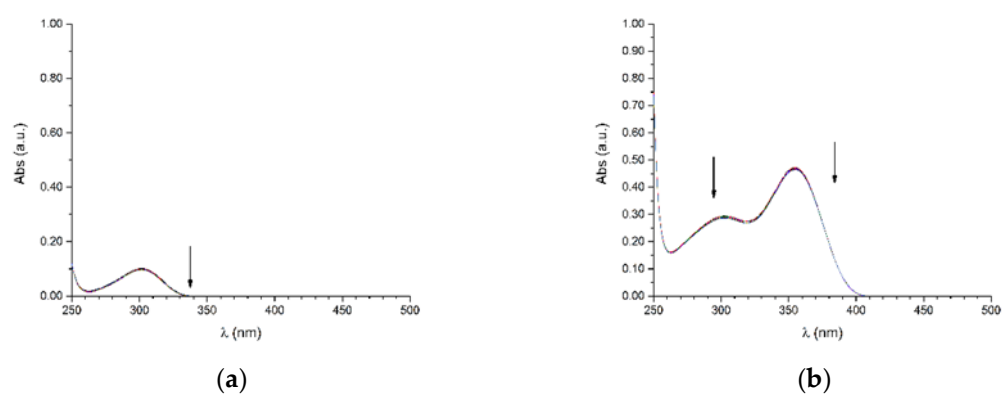


Figure 7. Acquired spectra for (a) Tests C1 and (b) Test C2.

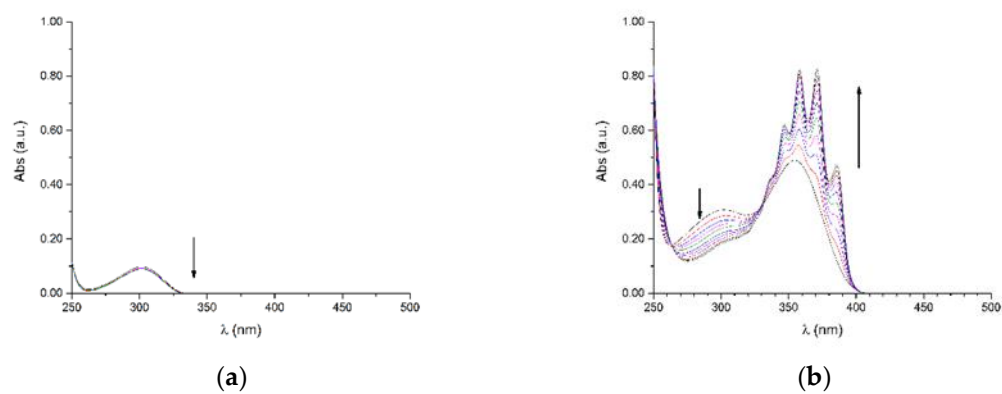


Figure 8. Acquired spectra for (a) Tests D1 and (b) Test D2.

Table 1. Irrigation tanks discrimination per fertilizer and supplier brand.

	Composition	Brand	Remarks ¹
T0	HNO ₃ (54%)	ICL	HNO ₃ (54%); d= 1.51
	H ₂ O		
T1	Ca(NO ₃) ₂	ICL Nova Calcium	Ca(NO ₃) ₂ : 15.5% N(total); 14.4% N(NO ₃); 1.1% N(NH ₃); 26.5% CaO
	(NH ₄)(NO ₃)	AgroMayor	(NH ₄)(NO ₃): 34.5% N(total); 16.9% N(NO ₃); 17.6% N(NH ₃)
	H ₂ O		
T2	KNO ₃	ICL Nova Nipo	KNO ₃ : 13% N(NO ₃); 46% K ₂ O
	KH ₂ PO ₄	ICL Nova MKP	KH ₂ PO ₄ : 52% P ₂ O ₅ ; 34% K ₂ O
	MgSO ₄	ICL Nova MagnesiumS	MgSO ₄ : 16% MgO; 32% SO ₃
	K ₂ SO ₄	Yara Krista SOP	K ₂ SO ₄ : 51% K ₂ O; 45% SO ₃
	Micronutrients	BIOMIP Microne	Micronutrients: 0.65% m/m B; 0.30% m/m Cu; 7.50% m/m Fe; 3.50% m/m Mn; 0.30% m/m Mo; 0.70% m/m Zn; 5.00% K ₂ O
	H ₂ O		

¹ Relevant information on product composition made available by manufacturers.

Table 2. Calibration values obtained from data, with linear and logarithmic correlations, respectively.

Test	Slope	y-intercept	R-square
A1	$2.10 \times 10^{-3} \pm 2.85 \times 10^{-5}$	$3.68 \times 10^{-2} \pm 1.35 \times 10^{-3}$	0.9984
A2	$1.79 \times 10^{-3} \pm 3.5 \times 10^{-5}$	$2.29 \times 10^{-1} \pm 1.65 \times 10^{-3}$	0.9966
B1	$-8.70 \times 10^{-6} \pm 2.02 \times 10^{-6}$	$1.26 \times 10^{-1} \pm 2.40 \times 10^{-3}$	0.6734
C1	$-1.72 \times 10^{-6} \pm 7.16 \times 10^{-7}$	$9.99 \times 10^{-2} \pm 8.52 \times 10^{-4}$	0.3903
C2	$-4.35 \times 10^{-6} \pm 3.83 \times 10^{-7}$	$2.94 \times 10^{-1} \pm 4.55 \times 10^{-4}$	0.9347
D1	$-5.64 \times 10^{-4} \pm 1.32 \times 10^{-4}$	$9.47 \times 10^{-2} \pm 8.95 \times 10^{-4}$	0.6697
	A	Reduced Chi-Sqr	R-Square
B2	199.37 ± 7.93	42.71	-36281.44
D2	1.52 ± 0.66	2.27	-1874.03

Table 3. Crossed interference matrix excerpt, with values of each ionic species (target), on two batches (Tests ID 1-6 and 7-12).

	T0	T1	T2		
				C (gmL ⁻¹)	
	N(NO ₃ ⁻)	N(NO ₃ ⁻)	N(NO ₃ ⁻)	K ⁺	P ⁵⁺
ID	1.35 × 10⁻⁴	1.11 × 10⁻²	3.39 × 10⁻³	1.49 × 10⁻²	3.85 × 10⁻³
1	4.51 × 10 ⁻⁵	2.95 × 10 ⁻³	1.13 × 10 ⁻³	4.95 × 10 ⁻³	1.28 × 10 ⁻³
2	3.61 × 10 ⁻⁵	2.95 × 10 ⁻³	1.13 × 10 ⁻³	4.95 × 10 ⁻³	1.28 × 10 ⁻³
3	2.71 × 10 ⁻⁵	2.95 × 10 ⁻³	1.13 × 10 ⁻³	4.95 × 10 ⁻³	1.28 × 10 ⁻³
4	1.80 × 10 ⁻⁵	2.95 × 10 ⁻³	1.13 × 10 ⁻³	4.95 × 10 ⁻³	1.28 × 10 ⁻³
5	9.02 × 10 ⁻⁶	2.95 × 10 ⁻³	1.13 × 10 ⁻³	4.95 × 10 ⁻³	1.28 × 10 ⁻³

6	0,00	2.95×10^{-3}	1.13×10^{-3}	4.95×10^{-3}	1.28×10^{-3}
7	4.51×10^{-5}	2.21×10^{-3}	1.13×10^{-3}	4.95×10^{-3}	1.28×10^{-3}
8	3.61×10^{-5}	2.21×10^{-3}	1.13×10^{-3}	4.95×10^{-3}	1.28×10^{-3}
9	2.71×10^{-5}	2.21×10^{-3}	1.13×10^{-3}	4.95×10^{-3}	1.28×10^{-3}
10	1.80×10^{-5}	2.21×10^{-3}	1.13×10^{-3}	4.95×10^{-3}	1.28×10^{-3}
11	9.02×10^{-6}	2.21×10^{-3}	1.13×10^{-3}	4.95×10^{-3}	1.28×10^{-3}
12	0.00	2.21×10^{-3}	1.13×10^{-3}	4.95×10^{-3}	1.28×10^{-3}