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Monitoring a zinc biofortification workflow in an experimental field of *Triticum aestivum* L. applying smart farming technology

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Abstract: The strong increase of the human population worldwide is demanding a food production, meeting quality standards. In this context, the agronomic biofortification with Zn is being widely used in staple food crops as a strategy to surpass micronutrient deficiencies. Conversely, as bread wheat is one of the most produced and consumed cereal, this staple food biofortification can be an opportunity to create an added value product. In this context, a workflow for Zn biofortification of *Triticum aestivum* L. (cvs Paiva and Roxo) crops, was implemented in an experimental field located in Beja, Portugal and smart farming techniques were used. Accordingly, images were collected by an Unmanned Aerial Vehicle before Zn foliar applications. Grain yield, test weight and thousand kernel weight were analyzed (post-harvest), after two foliar applications of $ZnSO_4$, in three concentrations (control – 0, 8.1 and 18.2 $kg.ha^{-1}$), at booting and heading stages. In general, when applying higher concentrations of foliar Zn, grain yield, test weight and thousand kernel weight decreased, slightly, in which Paiva presented higher values compared to Roxo. Nevertheless, the Normalized Difference Vegetation Index (NDVI) did not reveal a direct correlation between its higher values and the increase of grain yield. Yet, it was concluded that using drones is of utmost importance to decide whether an experimental field is qualified to implement a biofortification workflow.

Keywords: agronomic biofortification; bread wheat; grain yield; NDVI; test weight; thousand kernel weight

Materials and Methods

Triticum aestivum L. (cv. Roxo and Paiva)

↓

Experimental field (24 plots)

↓

UAV (NDVI)

↓

Agronomic biofortification with Zn

↓

Grain Yield, Test Weight and TKW

↓

Statistical analyses

Results and Discussion

Variety	Treatment	Replicated	Grain Yield (kg.ha^{-1})	Test Weight (kg.hL^{-1})	TKW (g)	NDVI ± STD
Paiva (P)	T0	1	452	75.9	42.3	0.431 ± 0.162
		2	802	40.5	38.7	0.489 ± 0.153
		3	1005	69.2	39.9	0.532 ± 0.151
		4	950	72.2	39.7	0.598 ± 0.135
	T1	1	621	74.1	38.3	0.458 ± 0.140
		2	1092	70.1	37.6	0.472 ± 0.149
		3	890	73.2	36.2	0.564 ± 0.138
		4	586	73.6	36.5	0.343 ± 0.185
	T2	1	447	74.2	37.1	0.517 ± 0.138
		2	647	71.7	38.5	0.525 ± 0.144
		3	916	67.4	35.8	0.495 ± 0.175
		4	579	73.4	36.8	0.557 ± 0.152
Roxo (R)	T0	1	582	76.3	33.4	0.388 ± 0.164
		2	1284	76.8	35.8	0.508 ± 0.157
		3	932	77.2	35.7	0.521 ± 0.154
		4	905	64.4	34.9	0.551 ± 0.154
	T1	1	766	76.0	32.8	0.474 ± 0.163
		2	971	68.1	32.0	0.500 ± 0.168
		3	679	73.9	31.8	0.462 ± 0.155
		4	472	74.4	33.2	0.538 ± 0.163
	T2	1	304	65.7	32.1	0.482 ± 0.154
		2	657	73.6	31.0	0.573 ± 0.135
		3	514	75.5	32.4	0.488 ± 0.176
		4	566	75.8	32.9	0.519 ± 0.158

The plots with the highest NDVI value show greater plant vigor and, in addition, plots with the lowest NDVI standard deviation (STD), show greater homogeneity in the vigor.

Results and Discussion

NDVI

Values < 0.44:

- R0S1
- P0S1
- P1S4

Values > 0.55:

- R0S4
- R2S2
- P0S4
- P1S3
- P2S4

Grain Yield

Values < 500 kg.ha^{-1}:

- R1S4
- R2S1
- P0S1
- P2S1

Values > 1000 kg.ha^{-1}:

- R0S2
- P0S3
- P1S2

Test Weight

Values < 70 kg.hL^{-1}:

- R0S4
- R1S2
- R2S1
- P0S2
- P0S3
- P2S3

Values > 75 kg.hL^{-1}:

- R0S1
- R0S2
- R0S3
- R1S1
- R2S3
- R2S4
- P0S1

TKW

Values < 33 g:

- R0S1
- R0S2
- R0S3
- R2S1
- R1S2

Values > 38 g:

- P0S1
- P0S2
- P0S3
- P0S4
- P1S1
- P2S2

The plots **R2S1** and **R1S2** presented lower values in grain yield (except R1S2), test weight and TKW.

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Results and Discussion

a)

Paiva T0	Grain Yield	Test Weight	TKW	NDVI
Grain Yield	1	-0.4	-0.2	0.8
Test Weight	-0.156	1	0.8	-0.2
TKW	-0.761	0.74	1	-0.4
NDVI	0.858	0.111	-0.569	1

b)

Paiva T1	Grain Yield	Test Weight	TKW	NDVI
Grain Yield	1	-0.8	0	0.8
Test Weight	-0.895	1	0.4	-0.6
TKW	-0.053	-0.099	1	-0.4
NDVI	0.59	-0.18	-0.093	1

c)

Paiva T2	Grain Yield	Test Weight	TKW	NDVI
Grain Yield	1	-1	-0.4	-0.4
Test Weight	-0.986	1	0.4	0.4
TKW	-0.503	0.504	1	0.4
NDVI	-0.564	0.695	0.331	1

d)

Roxo T0	Grain Yield	Test Weight	TKW	NDVI
Grain Yield	1	0.6	1	0.2
Test Weight	0.081	1	0.6	-0.2
TKW	0.895	0.084	1	0.2
NDVI	0.656	-0.5	0.809	1

e)

Roxo T1	Grain Yield	Test Weight	TKW	NDVI
Grain Yield	1	-0.4	-0.4	-0.2
Test Weight	-0.689	1	0.6	0
TKW	-0.623	0.527	1	0.8
NDVI	-0.426	-0.165	0.679	1

f)

Roxo T2	Grain Yield	Test Weight	TKW	NDVI
Grain Yield	1	0.4	-0.2	1
Test Weight	0.826	1	0.8	0.4
TKW	-0.332	0.192	1.0	-0.2
NDVI	0.83	0.376	-0.683	1

Correlations with NDVI

- Strong and positive (> 0.70)
- Weak and positive (< 0.30)
- Weak and negative (< -0.30)
- Null (≈ zero)

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Results and Discussion

Correlations with NDVI

Strong and positive Correlation

- **Paiva T0** (between NDVI and grain yield, for CP and CS)
- **Roxo T2** (between NDVI and grain yield, for CP and CS)
- **Paiva T1** (between NDVI and grain yield, for CS)
- **Roxo T0** (between NDVI and TKW, for CP)
- **Roxo T1** (between NDVI and TKW, for CS)

Weak and positive Correlation

- **Paiva T0** (between NDVI and test weight for CP)
- **Paiva T2** (between NDVI and TKW for CP)
- **Roxo T0** (between NDVI and grain yield and between NDVI and TKW, both for CS)

Weak and negative Correlation

- **Paiva T1** (between NDVI and test weight for CP)
- **Roxo T1** (between NDVI and grain yield - CS and between NDVI and TKW - CP)
- **Paiva T0** (between NDVI and test weight for the CS)
- **Roxo T0** (between NDVI and test weight for the CS)
- **Roxo T2** (between NDVI and TKW for the CS)

Null Correlation

- **Paiva T1** (between NDVI and TKW (only in CP))
- **Roxo T1** (between NDVI and test weight (only in CS))

Spearman Coefficient (CS)

Pearson Coefficient (CP)

All the other samples have an **intermediate correlation with NDVI**, whether **positive** or **negative**.

Results and Discussion

- NDVI values refer to a date prior to the two applications of $ZnSO_4$ (which occurred during the month of April), analysis can only be drawn regarding the comparison between the two varieties Paiva and Roxo and to the differences presented by all plots (considering all of them as "control" as $ZnSO_4$ foliar applications did not occur at the time of the flight);
- For samples Paiva T0, Paiva T1 and Roxo T2, the correlation between NDVI and grain yield is in line with the values presented in the table 1, as when the grain yield rises/fall so does the values of NDVI;

- The samples Roxo T0 and T1 show a weak correlation between NDVI and grain yield, since when the NDVI was lower, the grain yield was higher, comparing the four plots of the sample. This might occur because some plants possibly had more grain stored than others, resulting in higher grain yield values and lower values of NDVI, as the plots presented less plants (*i.e.* lower values of NDVI). The opposite can happen by having higher plant density in the plots, but a smaller number of grains stored in each plant, resulting in lower values of grain yield and higher values of NDVI, when comparing the four plots of the same sample;
- In plots where the NDVI values are less than 0.44, it may be due to the fact that sowing did not took place in the usual way, with flaws appearing in these plots.

Conclusions

- Grain yield, test weight and TKW decreased slightly, when applying higher concentrations of foliar Zn (with Paiva presenting higher values relatively to Roxo);
- NDVI did not reveal a direct correlation between its higher values and test weight and TKW;
- Grain yield showed a strong and positive correlation with NDVI for both coefficients (Pearson and Spearman) in some samples, but just when averaging the four plots of samples and not in separated plots;
- Using UAVs was of utmost importance to decide whether this experimental field was qualified to implement the biofortification workflow of *Triticum aestivum* L.

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