



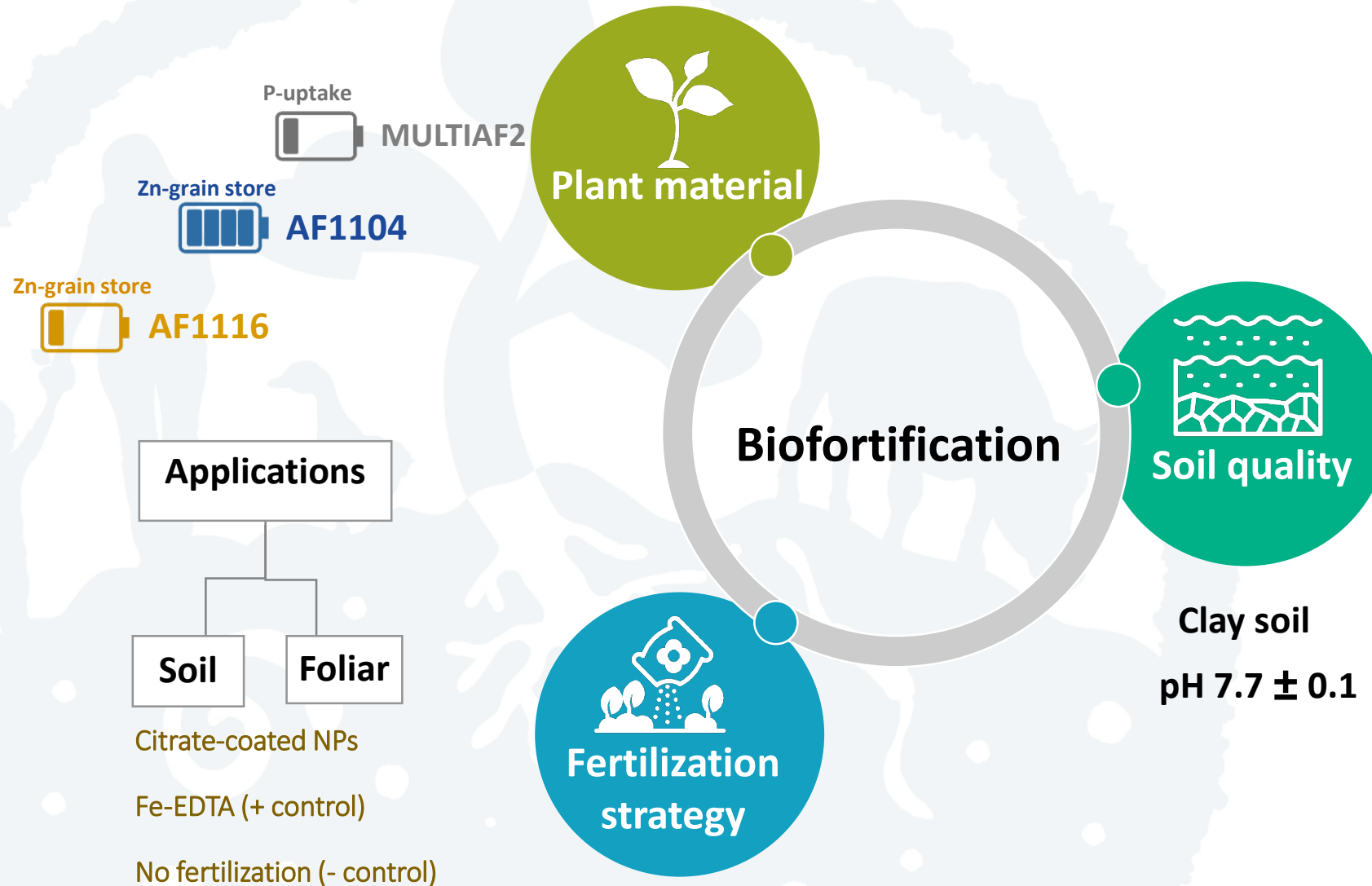
Can cobalt-ferrite nanoparticles be an alternative fertilizer for the agronomic iron fortification of wheat?

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Materials and methods



Feature	Unit	Value
Organic matter	%	5.7 ± 0.40
N inorganic	mg kg ⁻¹	29.5 ± 5.48
P		49.6 ± 13.95
Exchangeable cations		
Na	cmol ₍₊₎ kg ⁻¹	1.0 ± 0.01
K		5.4 ± 0.08
Ca		88.9 ± 5.04
Mg		11.9 ± 0.80
Micronutrients (DTPA extraction)		
Cu	mg kg ⁻¹	0.5 ± 0.02
Fe		3.2 ± 0.31
Zn		1.2 ± 0.01
Mn		14.9 ± 0.31

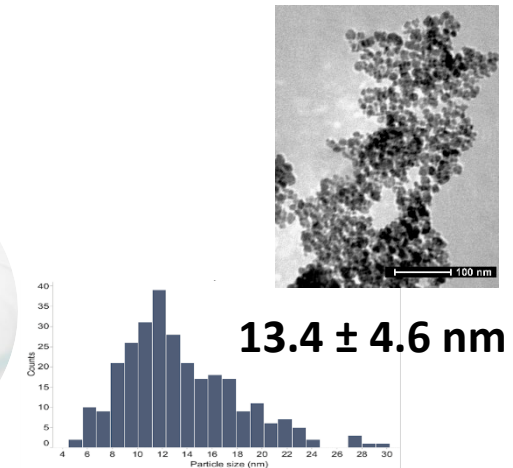
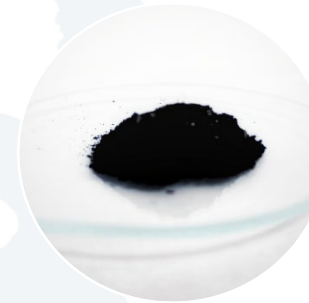
Materials and methods

What dose of NPs should I apply?

Type application	Treatment	Dose (Fe mg kg ⁻¹)
Without fertilization	Control	0
Soil application	Fe-EDTA	46
	NPs 46	46 (98 mg NPs kg ⁻¹)
	NPs 68	68 (145 mg NPs kg ⁻¹)
Foliar application	Fe-EDTA	330
	NPs	330

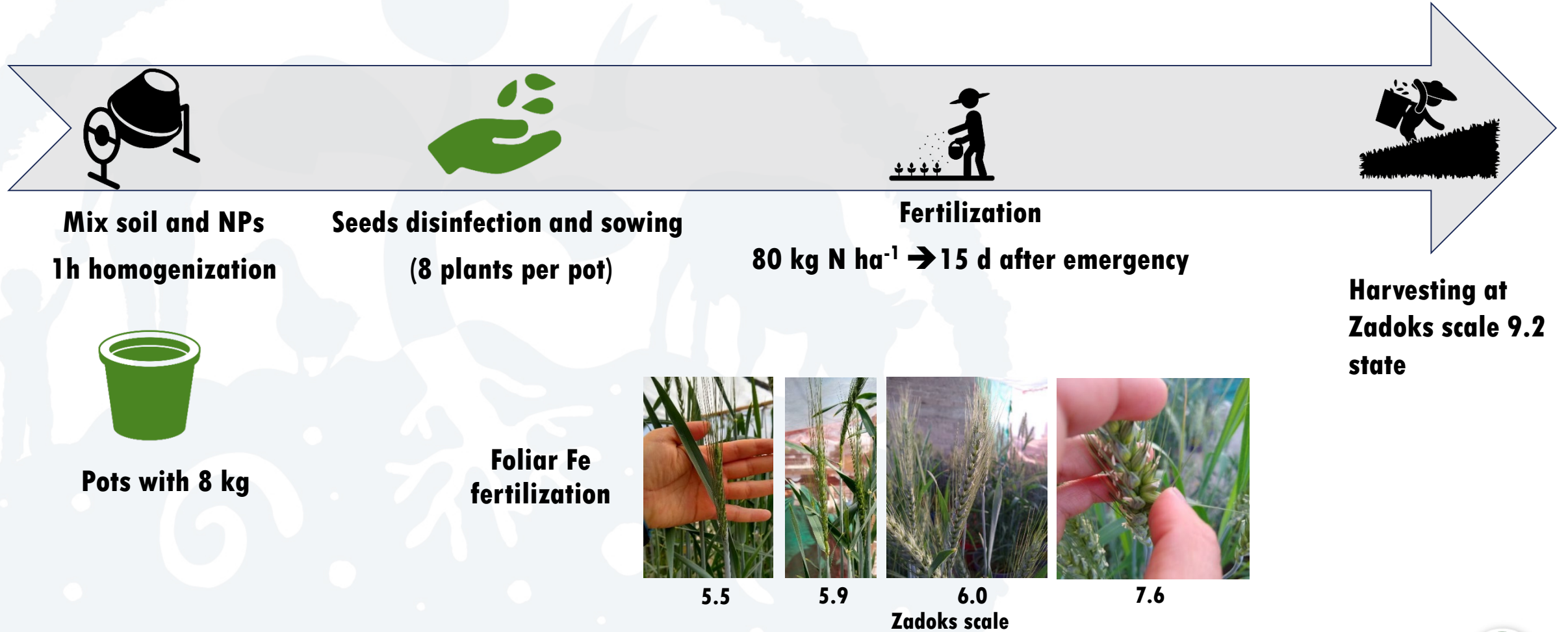
Iron fixation test

- | Dose | DTPA extraction |
|-------------------------------|-----------------------------|
| • 45 mg Fe kg ⁻¹ → | 9.5 mg Fe kg ⁻¹ |
| • 68 mg Fe kg ⁻¹ → | 13.0 mg Fe kg ⁻¹ |
- >4.5 mg DTPA extractable Fe kg⁻¹ **adequate**
(NOM-021-RECENAT-2000)



Primary size of NPs

Materials and methods



Results

Agronomic traits of wheat plants fertilized with citrate-coated CoFe_2O_4 NPs or Fe-EDTA salt by soil or foliar applications

Treatment	Mean tillers per plant	Spikes number per pot	Biological yield per pot (g)	Grains number per pot	Grain yield per pot (g)	Thousand kernel weight (g)	Harvest index (%)
Control	4 ± 2 c	32 ± 13 c	89 ± 28 c	796 ± 223 b	39 ± 7 c	49 ± 7 a	45 ± 8 ab
Soil	FeEDTA	5 ± 2 abc	43 ± 17 abc	119 ± 41 ab	1012 ± 320 ab	48 ± 8 bc	49 ± 9 a
	NPs 46	5 ± 1 bc	41 ± 8 bc	99 ± 22 bc	875 ± 220 b	41 ± 13 c	47 ± 7 ab
	NPs 68	5 ± 2 bc	39 ± 13 bc	124 ± 27 ab	1219 ± 270 a	59 ± 17 a	48 ± 6 a
Foliar	FeEDTA	7 ± 2 a	55 ± 17 a	129 ± 34 a	1251 ± 381 a	51 ± 6 ab	43 ± 7 b
	NPs	6 ± 2 ab	45 ± 15 ab	118 ± 34 abc	1149 ± 245 a	52 ± 5 ab	46 ± 8 ab

Mean ± standard deviation of n=3. Different letters represent significant differences between treatments (Tukey $\alpha=0.05$)

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Grain yield

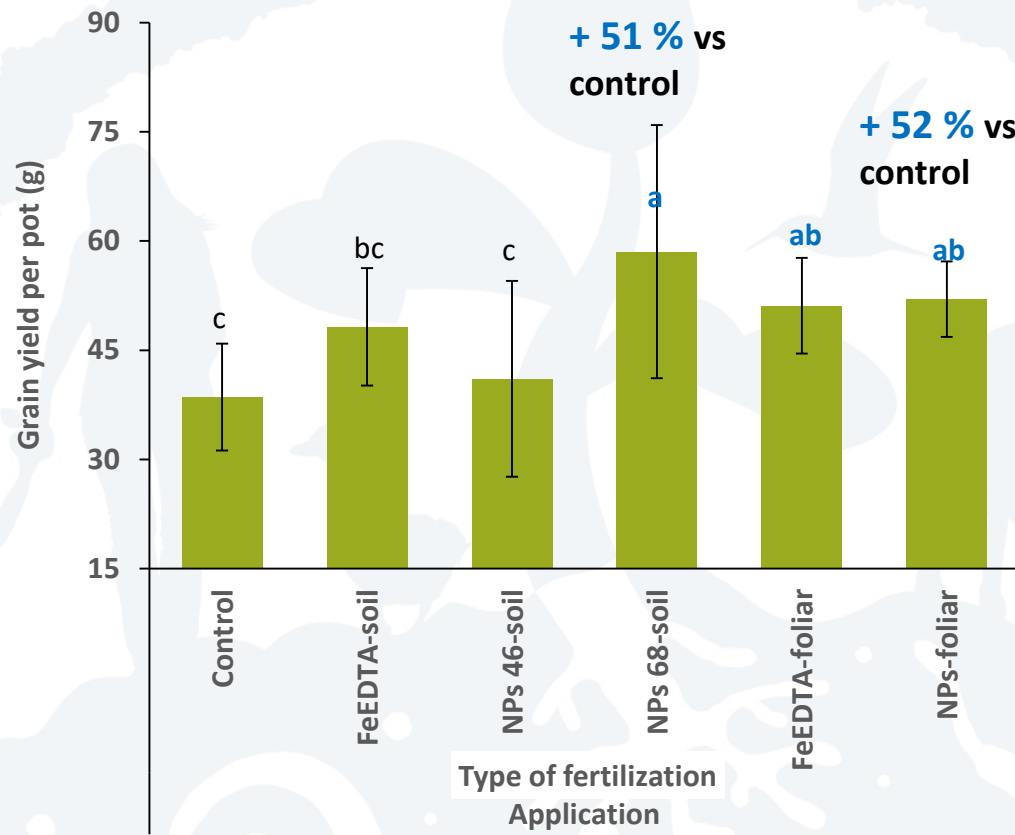


Fig. 1. Comparison of the grain yield according to the **type of fertilization**.

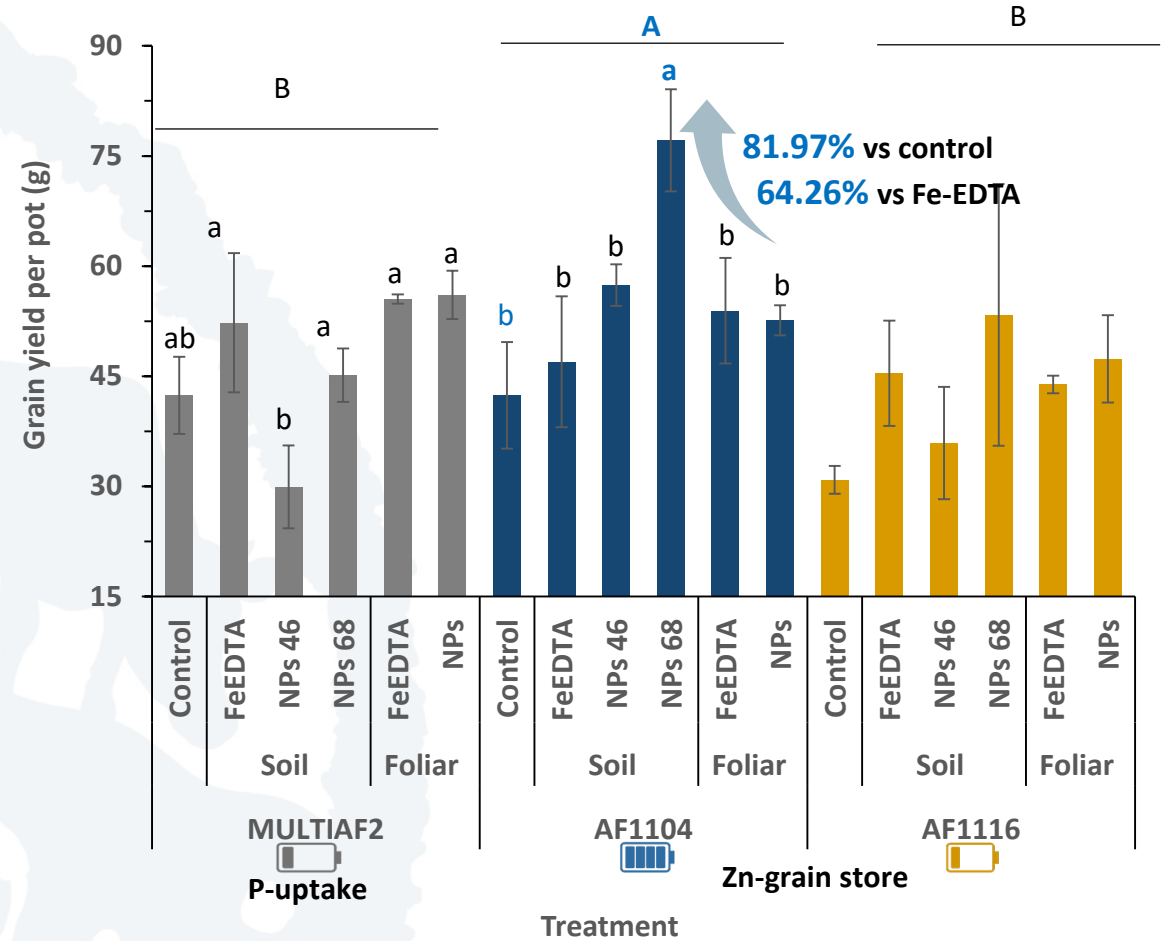


Fig. 2. Comparison of the grain yield according to the **type of fertilization** and **wheat line**.

[Fe] biofortification and phytic acid

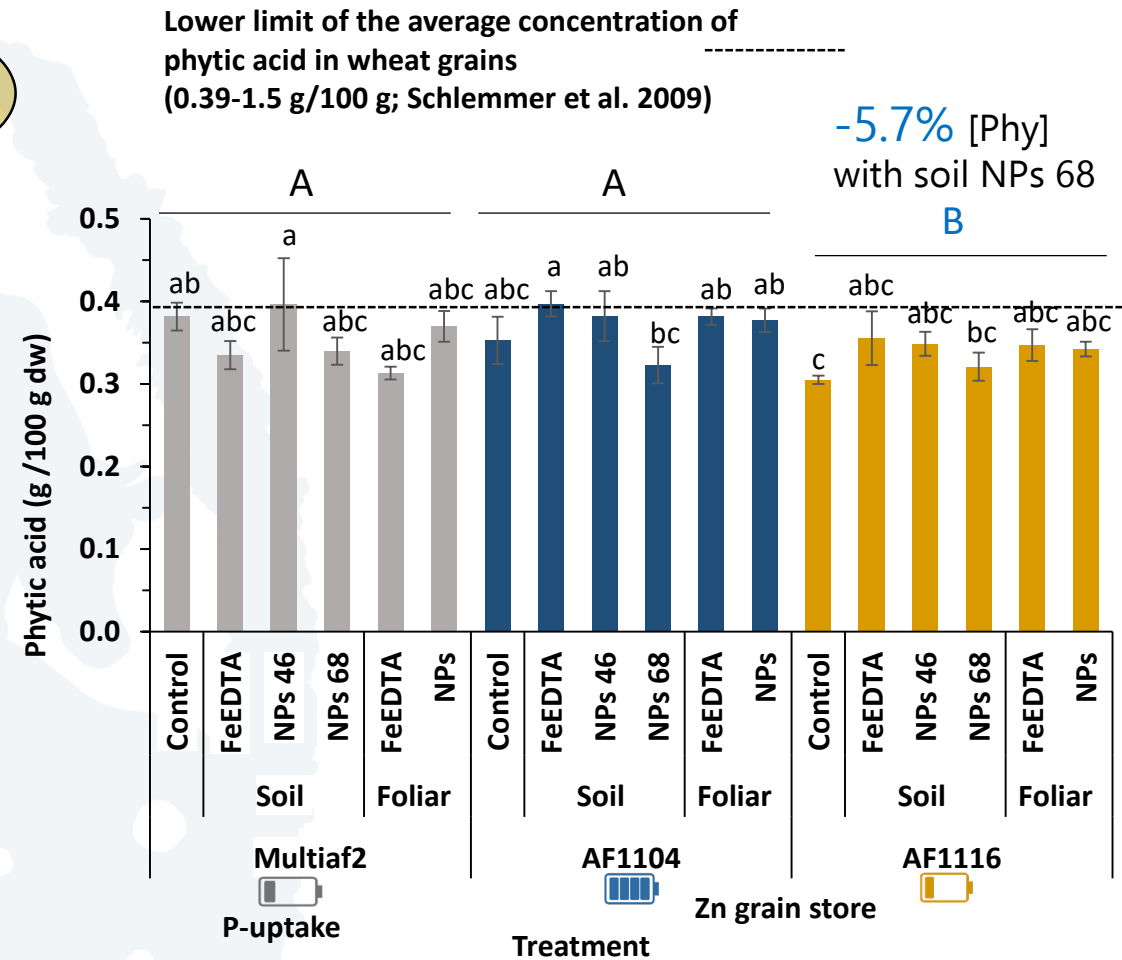
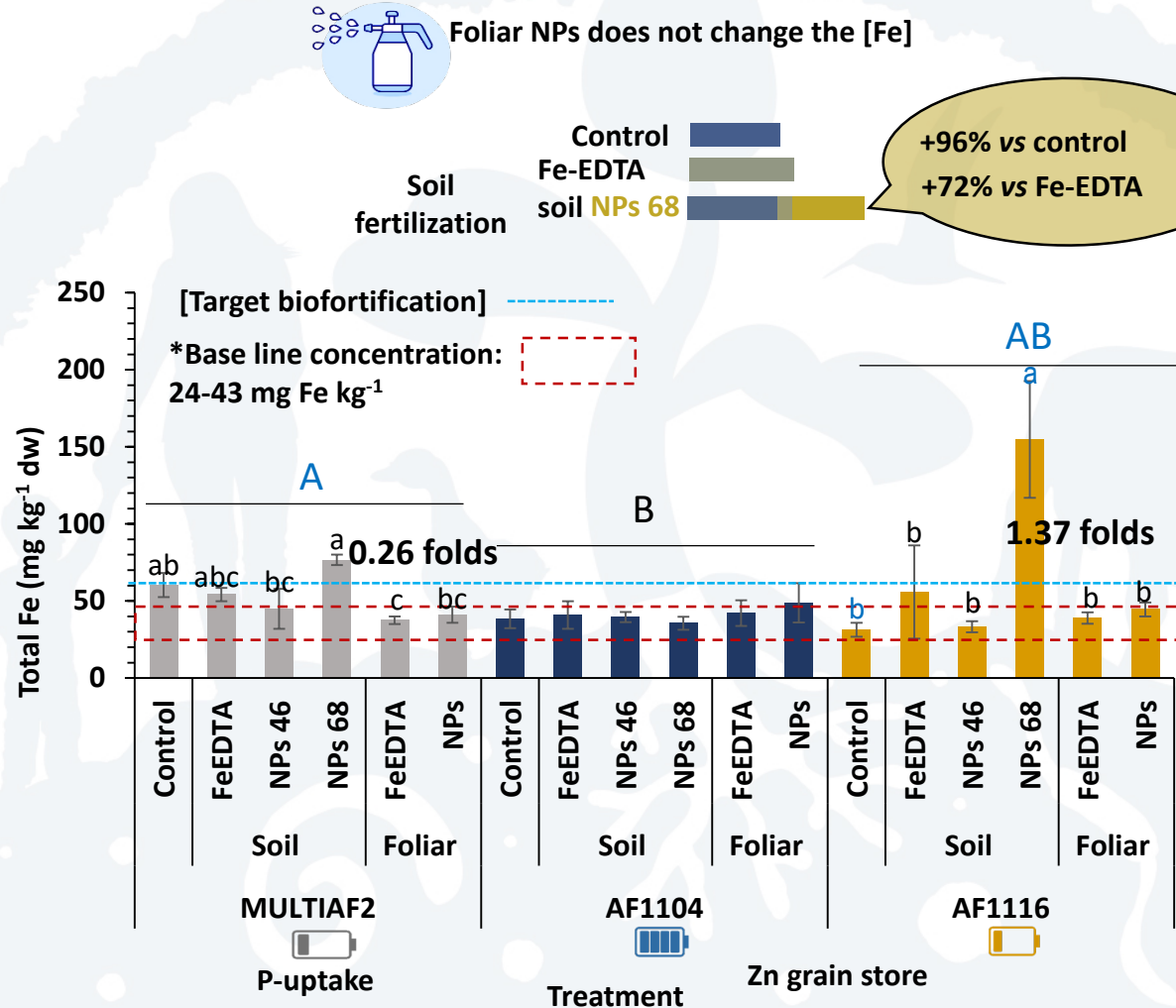


Fig. 3. Comparison of the Fe and phytic acid concentration in wheat grains according to the type of fertilization and wheat line

Molar ratio phytic acid and iron

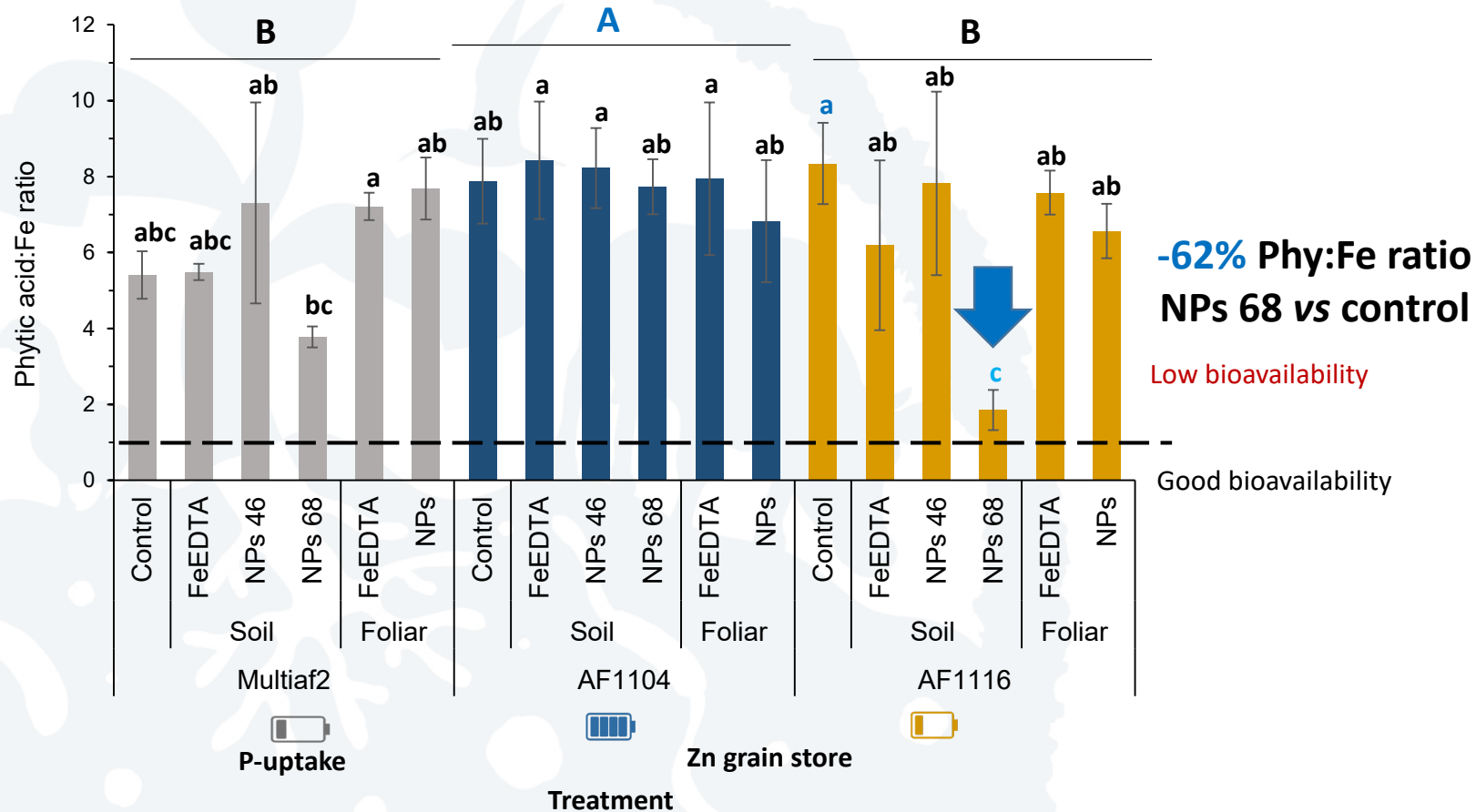


Fig. 4. Comparison of the molar ratio of phytic acid and Fe in wheat grains according to the type of fertilization and wheat line

Conclusions

- Use citrate-coated cobalt ferrite NPs may be a promising approach and effective tool for **wheat biofortification**.
- Applying NPs can increase or keep a similar **grain yield** compared to the plants without fertilization and Fe-EDTA fertilization (taking into account the soil quality used in this experiment).
- The **relative Fe bioavailability was improved in grains** of plants fertilized with NPs by soil application (68 mg Fe kg⁻¹)
- Further research should ensure they are **safe** for users, the environment, and food consumers.



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