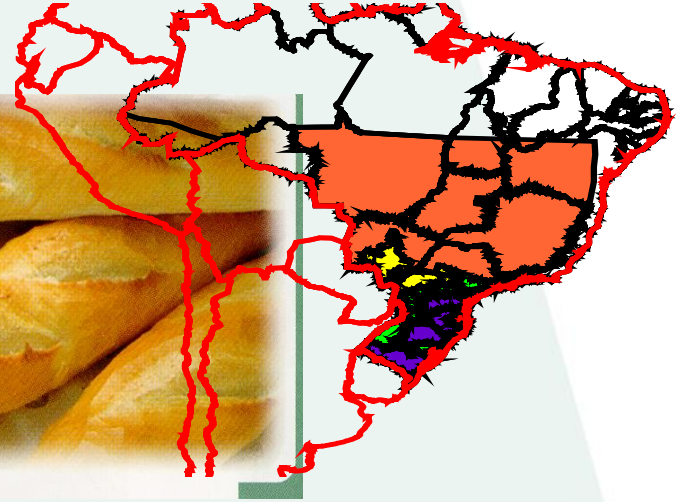
# BIOFORTIFICATION IN BRAZIL: IRON AND ZINC CONCENTRATION IN GRAINS OF WHEAT CULTIVARS GROWN IN DIFFERENT ENVIRONMENTS



*Dr. Pedro Luiz Scheeren – Embrapa Trigo - Brazil*

*Mexico City, Mexico, March 2018*

Embrapa

# BIOFORTIFICATION IN BRAZIL: IRON AND ZINC CONCENTRATION IN GRAINS OF WHEAT CULTIVARS GROWN IN DIFFERENT ENVIRONMENTS

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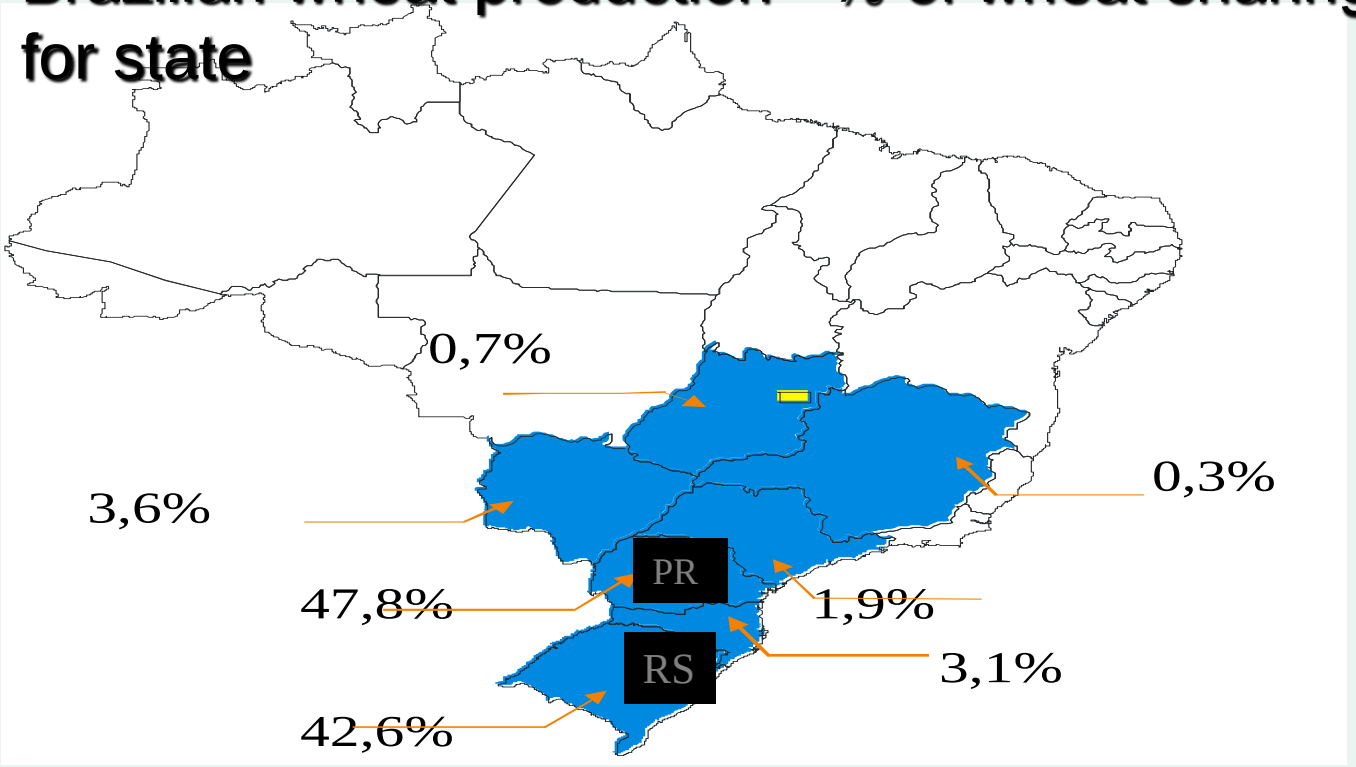
Embrapa

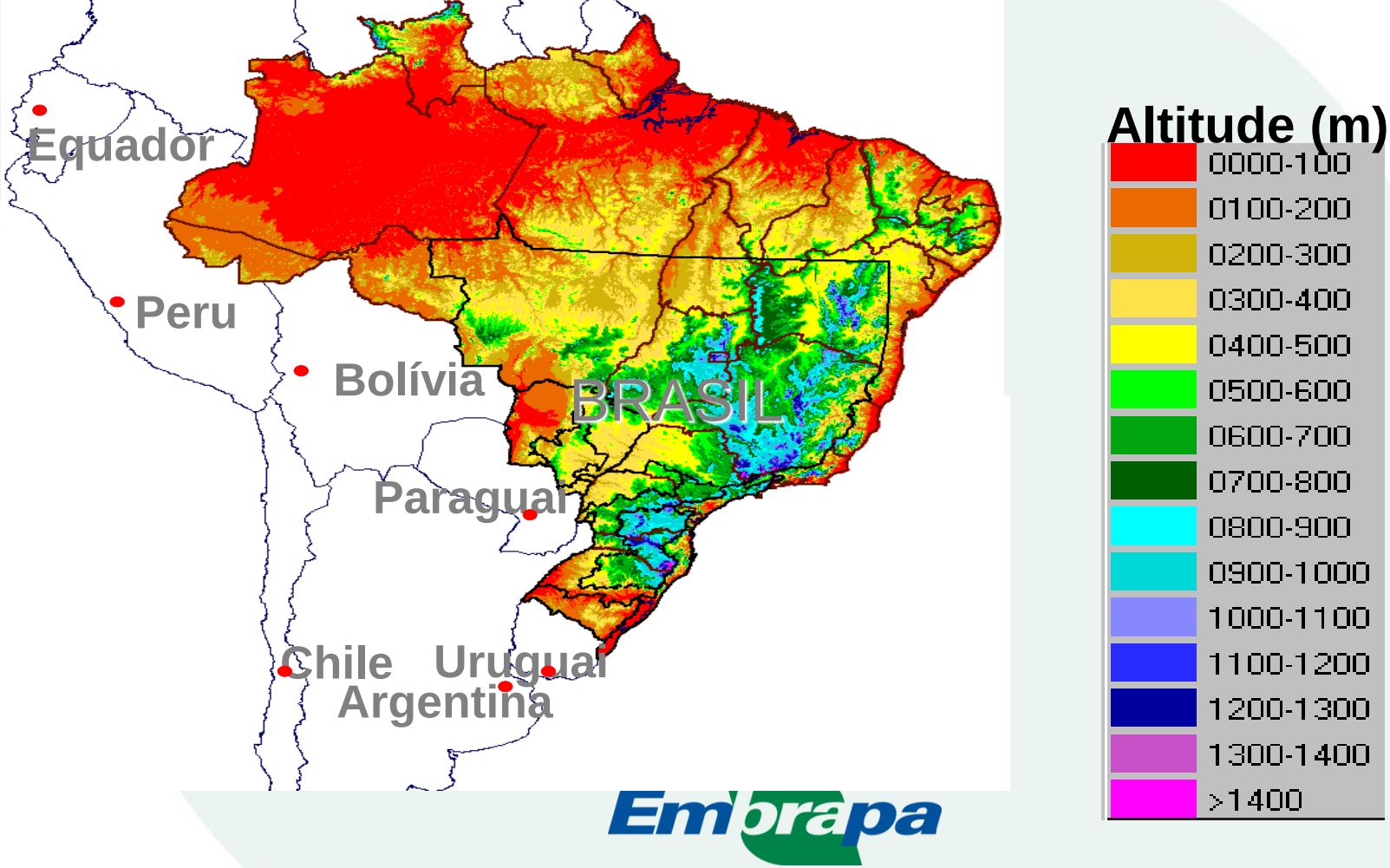
Embrapa

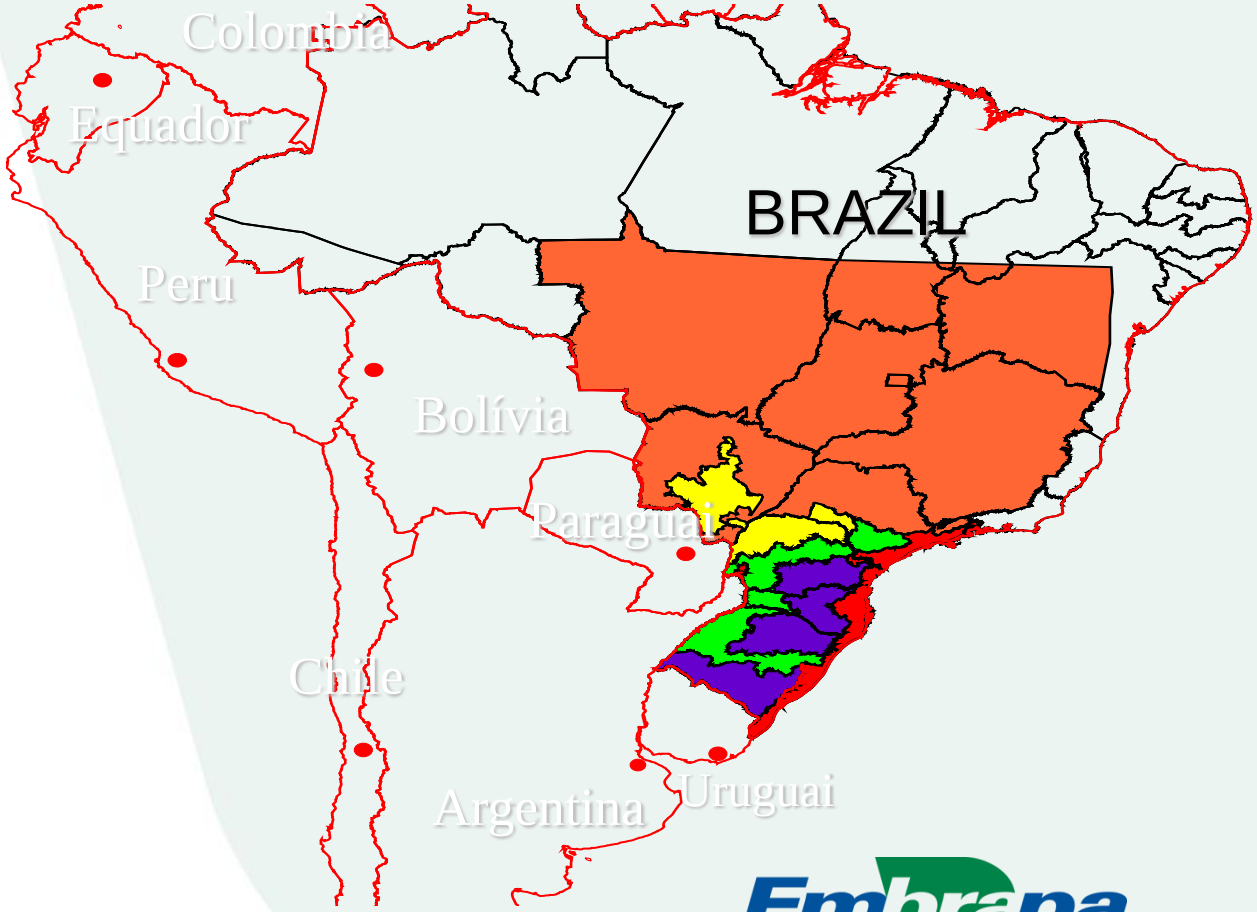
# Rede Embrapa de Inovação

# Brazilian wheat production - % of wheat sharing for state




**RS and PR = >90% of Brasilian Wheat Production**


Equador
Peru
Bolívia
BRASIL
Paraguai
Chile
Uruguai
Argentina
Altitude (m)
0000-100
0100-200
0200-300
0300-400
0400-500
0500-600
0600-700
0700-800
0800-900
0900-1000
1000-1100
1100-1200
1200-1300
1300-1400
>1400




VCU 1 - Temperate & Humid (High rainfall)

VCU 2 - Warm & Humid - High rainfall

VCU 3 - Warm & low rainfall

VCU 4 - Cerrado Warm & dry

Embrapa

# Background

- ✓ Wheat is consumed all around the world and it is a raw material of great potential. The production worldwide is over 700 million tons.
- ✓ Wheat is a carbohydrate-rich cereal and contains near all the amino acids that we need.
- ✓ In wheat, iron and zinc are mainly found near the aleurone layer of grains.

# Background

- ✓ Iron (Fe) is important in all tissues of the body for basic cellular functions and is indispensable for the muscles, the brain and red blood cells;
- ✓ Zinc (Zn) is essential for the activity of more than 300 enzymes, it is linked in mitotic processes, DNA synthesis, proteins, expression and gene activation, which justifies their importance during the gestation period (RIOS et al. , 2009);
- ✓ The recommended daily intake of Fe is 8 mg for men and 18 mg for women of childbearing age, and for Zn the recommended intake is 8 mg for women and 11 mg for men (COZZOLINO, 2007);

# Background

- In Brazil, the current wheat consumption is around 10.5 million tons (around 50 kg per capita)

- Fortification of food with nutrients is a practice accepted and used by food processors since the mid-twentieth century.

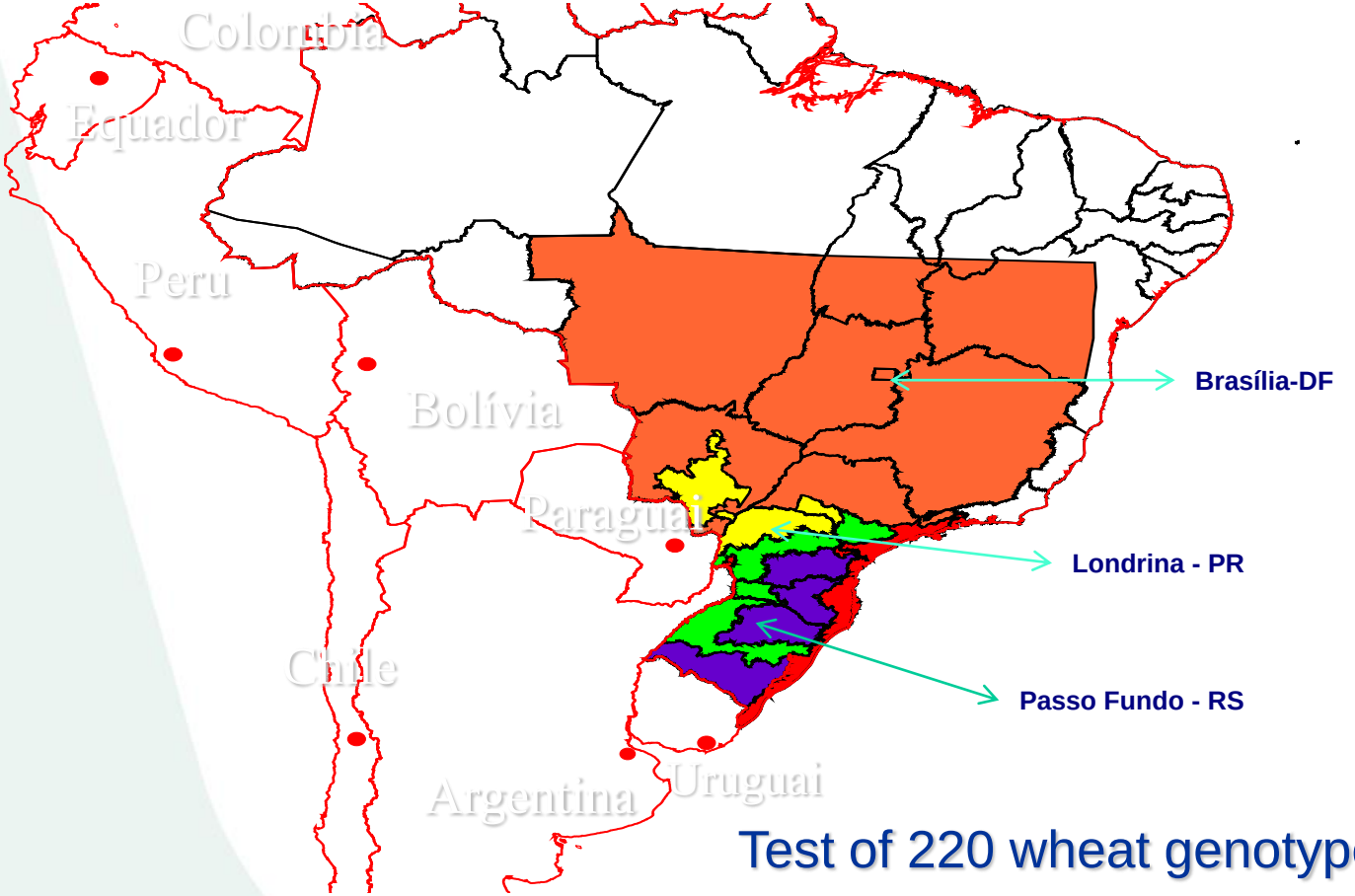
- In Brazil, fortification of wheat and corn flours, with iron and folic acid, has been mandatory since 2002, Resolution RDC No. 344 (BRASIL, 2002);

# Background

- ✓ The FAO Harvest Plus program is working on biofortification of human food with the objective to obtain biofortified agricultural products, because Iron and Zinc are important to human nutrition and for human health.
- ✓ In Brazil, the Embrapa's wheat program begun the research of Wheat Biofortification in 2009. Since this time, many genotypes were characterized for iron and zinc concentration in the grains and many "wheat X wheat" crosses were made.

# Background of Wheat Biofortification in Brazil 2009-2016

## First results - 2009




# Test of 220 wheat genotypes – Brazil, 2009

# Analisys of Iron concentration in grains of 220 wheat genotypes in three environmentals in Brazil - 2009

| Locality | Iron average (mg.kg-1) | Index |
|---|---|---|
| Brasília | 34,29 | 1,6563 |
| Londrina | 28,59 | -4,0456 |
| Passo Fundo | 35,02 | 2,3893 |

# *Iron concentration in 220 wheat genotypes – Brazil, 2009*

| | Iron concentration in grains (mg.kg-1) | | | |
|---|---|---|---|---|
| **Locality** | **Maximum** | **Genotype** | **Minimum** | **Genotype** |
| **Brasília-DF** | **55,75** | **IAS 54-Sel21** | **24,30** | **IPR 129** |
| **Londrina-PR** | **41,60** | **Ponta Grossa 1** | **21,95** | **OR 1** |
| **Passo Fundo-RS** | **49,62** | **Triplo Anão** | **25,90** | **IPR 128** |

# Analisys of Zinc concentration in grains of 220 wheat genotypes in three environmentals in Brazil – 2009 (“adaptability and estability”)

| Locality | Zinc average (mg.kg-1) | Index |
|---|---|---|
| Passo Fundo | 30,65 | -1,1155 |
| Londrina | 30,55 | -1,2208 |
| Brasília | 34,10 | 2,3363 |

# Zinc concentration in 220 wheat genotypes – Brazil, 2009

| | Zinc concentration in grains (mg.kg-1) | | | |
|---|---|---|---|---|
| Locality | Maximum | Genotype | Minimum | Genotype |
| Brasília - DF | 46,70 | Fronteira | 20,99 | Supera |
| Londrina - PR | 55,10 | Trigo Chapéu | 22,25 | BR 17 |
| Passo Fundo - RS | 49,37 | BRS Guamirim | 24,62 | Safira |

# Background

## Results - 2010

## *Iron concentration in 180 wheat cultivars – Passo Fundo, RS, BR - 2010*

| | | | |
|---|---|---|---|
| **Mean** | **33.01 mg.kg-1** | **CV(%)** | **2.169** |
| **Minimum** | **25.622 mg.kg-1** | **Maximum** | **45.719 mg.kg-1 (PG1)** |
| **LSD-Tukey(1%)** | **3.390821** | **LSD-Tukey (5%)** | **3.103042** |

# ZINC CONCENTRATION IN 180 WHEAT CULTIVARS
# PASSO FUNDO, RS, BR - 2010

| | | | |
|---|---|---|---|
| Average | 28.3 mg.kg-1 | CV(%) | 2.261 |
| Minimum | 19.104 mg.kg-1 | Maximum | 41.17 mg.kg-1 (Jesuita) |
| LSD -Tukey(1%) | 3.031399 | LSD -Tukey(5%) | 2.774124 |

# Results - 2013

- **???? Discussion about sampling protocols for micronutrient analysis of the HarvestPlus Biofortification Program (STANGOULIS & SISON, 2008)?????**

# HARVEST:

## Manually (by hand)
## or
## Mechanized (by machine)?

- Manual harvest

Figure 2 – Manual wheat harvest. Passo Fundo, 2013

Figure 3 – Manual harvest - spikes were bagged to avoid contamination.

Passo Fundo. 2013.

Figure 4 - Grain threshing of wheat without the use of metallic equipment, Passo Fundo, 2013.

Figure 5 - Separation of straw and grains with the aid of plastic boxes, Passo Fundo, 2013.

Figure 6 - Grains of wheat, straw and other materials in non metallic trays.

Passo Fundo, 2013.


Figure 7 - Removal of remaining straw and other foreign material from the grains using forced air flow.

Passo Fundo, 2013.

# IRON AND ZINC CONCENTRATIONS IN GRAINS OF DIFFERENT WHEAT (Triticum aestivum L.) CULTIVARS UNDER MANUAL AND MECHANIZED HARVEST - 2013

**LAZZAROTTO et al.**

# OBJECTIVES

- To quantify the concentrations of Fe and Zn in the grains of cultivars from the recommended list of wheat cultivars State of Rio Grande do Sul (EECT-RS) - 2013;
- To evaluate the influence of manual or mechanized grain harvest on the concentrations of Fe and Zn in wheat grains.

# Material and methods

- Experimental field of Embrapa Wheat;
- 30 wheat cultivars of the State Trial of Wheat Cultivars - RS;
- Seeding: July 1, 2013;
- Plots of 2.4 $m^2$, with 330 seeds $m^{-2}$;
- Design: randomized blocks with 4 replications (for each harvest method).

# Material and Methods

Harvest:

- Manually (Handmade);
- Mechanized* Harvest (by machine*).

- *Different from the protocols of harvest of HarvestPlus Program of Biofortification (STANGOULIS & SISON, 2008);

# Material and Methods

**The plots were**

**harvested manually and**

**mechanically;**

# RESULTS AND DISCUSSION

## Iron concentration in wheat grains

# RESULTS AND DISCUSSION

Table 2 - Analysis of Variance (ANOVA) for the genotypes and harvesting factors, manual and mechanized, and their interaction in Iron concentrations in the grains of different wheat genotypes harvested in Passo Fundo - 2013

| Source | DF | SS | SM | F | P | |
|---|---|---|---|---|---|---|
| Blocks | 3 | 19,44 | 6,48 | 3,79 | 0,01 | * |
| Main effects | | | | | | |
| Genotypes | 29 | 6738,00 | 232,35 | 135,77 | 0,00 | *** |
| Grain harvest methods | 1 | 2,39 | 2,39 | 1,39 | 0,24 | ns |
| Interaction | | | | | | |
| Genotype x Grain harvest methods | 29 | 46,80 | 1,61 | 0,94 | 0,55 | ns |
| Error | 417 | 713,57 | 1,71 | | | |
| Total | 479 | 7520,23 | | | | |
| CV | 3,93% | | | | | |

*: 5% significant; ***: significant at 1%; ns: not significant

# RESULTS AND DISCUSSION

Table 3 - Iron concentration in the grains of different wheat genotypes harvested in Passo Fundo - 2013

| Classificação | Genótipo | Média Fe (mg kg$^{-1}$) |
|---|---|---|
| 1 | BRS Parrudo | 41,32 a |
| 2 | BRS 327 | 38,70 b |
| 3 | BRS 331 | 37,94 b |
| 4 | CD 1440 | 37,85 b |
| 5 | BRS Guamirim | 37,19 c |
| 6 | TEC Vigore | 36,78 c |
| 7 | CD 1550 | 36,11 d |
| 8 | Topázio | 35,89 d |
| 9 | JF 90 | 35,65 d |
| 10 | Fundacep 52 | 35,33 d |
| 11 | Jadeíte 11 | 35,22 d |
| 12 | BRS 328 | 34,53 e |
| 13 | TBIO Tibagi | 34,31 e |
| 14 | Fundacep Raízes | 33,79 e |
| 15 | TEC Frontale | 33,69 e |
| 16 | Fundacep Bravo | 33,42 e |
| 17 | TBIO Mestre | 33,22 e |
| 18 | TBIO Seleto | 32,79 f |
| 19 | TBIO Alvorada | 32,55 f |
| 20 | Fundacep Horizonte | 32,34 f |
| 21 | Marfim | 32,30 f |
| 22 | Estrela Atria | 31,89 f |
| 23 | Ametista | 31,54 g |
| 24 | TBIO Pioneiro | 30,77 g |
| 25 | Mirante | 29,61 h |
| 26 | Campeiro | 29,17 h |
| 27 | TBIO Sinuelo | 28,16 h |
| 28 | Quartzo | 26,72 i |
| 29 | TBIO Iguaçu | 25,85 i |
| 30 | TBIO Itaipú | 25,75 i |
| | Média geral | 33,35 |
| | C.V. | 3,85 % |

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error.

# RESULTS AND DISCUSSION

Table 3 - Iron concentration in the grains of different wheat genotypes harvested in Passo Fundo - 2013

| Classification | Genotype | Fe (mg kg$^{-1}$) | |
|---|---|---|---|
| 1 | BRS Parrudo | 41,32 | a |
| 2 | BRS 327 | 38,70 | b |
| 3 | BRS 331 | 37,94 | b |
| 4 | CD 1440 | 37,85 | b |
| 5 | BRS Guamirim | 37,19 | c |
| 6 | TEC Vigore | 36,78 | c |
| 7 | CD 1550 | 36,11 | d |
| 8 | Topázio | 35,89 | d |
| 9 | JF 90 | 35,65 | d |
| 10 | Fundacep 52 | 35,33 | d |
| 11 | Jadeíte 11 | 35,22 | d |
| 12 | BRS 328 | 34,53 | e |
| 13 | TBIO Tibagi | 34,31 | e |
| 14 | Fundacep Raízes | 33,79 | e |
| 15 | TEC Frontale | 33,69 | e |
| 16 | Fundacep Bravo | 33,42 | e |
| 17 | TBIO Mestre | 33,22 | e |
| 18 | TBIO Seleto | 32,79 | f |
| 19 | TBIO Alvorada | 32,55 | f |
| 20 | Fundacep Horizonte | 32,34 | f |
| 21 | Marfim | 32,30 | f |
| 22 | Estrela Atria | 31,89 | f |
| 23 | Ametista | 31,54 | g |
| 24 | TBIO Pioneiro | 30,77 | g |
| 25 | Mirante | 29,61 | h |
| 26 | Campeiro | 29,17 | h |
| 27 | TBIO Sinuelo | 28,16 | h |
| 28 | Quartzo | 26,72 | i |
| 29 | TBIO Iguaçu | 25,85 | i |
| 30 | TBIO Itaipú | 25,75 | i |
| | Média geral | 33,35 | |
| | C.V. | 3,85 % | |

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# RESULTS AND DISCUSSION

Table 3 - Iron concentration in the grains of different wheat genotypes harvested in Passo Fundo - 2013

| Classification | Genotype | Fe (mg kg$^{-1}$) | |
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| 3 | BRS 331 | 37,94 | b |
| 4 | CD 1440 | 37,85 | b |
| 5 | BRS Guamirim | 37,19 | c |
| 6 | TEC Vigore | 36,78 | c |
| 7 | CD 1550 | | |
| 8 | Topázio | | |
| 9 | JF 90 | | |
| 16 | Fundacep Bravo | 33,42 | e |
| 17 | TBIO Mestre | 33,22 | e |
| 21 | | | f |
| 22 | | | f |
| | | | g |
| | | | g |
| | | | h |
| 26 | Campeiro | 29,17 | h |
| 27 | TBIO Sinuelo | 28,16 | h |
| 28 | Quartzo | 26,72 | i |
| 29 | TBIO Iguaçu | 25,85 | i |
| 30 | TBIO Itaipú | 25,75 | i |
| | Média geral | 33,35 | |
| | C.V. | 3,85 % | |

**7,54% seeds disp.**

**$\overline{X}$=38,95 mg kg$^{-1}$**

**41% superior**

**66% seeds disp.**

**$\overline{X}$= 26,11 mg kg$^{-1}$**

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# RESULTS AND DISCUSSION

## Zinc concentration in wheat grains

# RESULTS AND DISCUSSION

Table 2 - Analysis of Variance (ANOVA) for the genotypes and harvesting factors, manual and mechanized, and their interaction in Zinc concentrations in the grains of different wheat genotypes harvested in Passo Fundo - 2013

| Source | DF | SS | SM | F | P | |
|---|---|---|---|---|---|---|
| Blocks | 3 | 42,55 | 14,18 | 4,04 | 0,01 | * |
| Main effects | | | | | | |
| Genotypes | 29 | 3239,59 | 111,71 | 31,84 | 0,00 | *** |
| Grain harvest methods | 1 | 0,31 | 0,31 | 0,09 | 0,77 | ns |
| Interaction | | | | | | |
| Genotype x Grain harvest methods | 29 | 76,90 | 2,65 | 0,76 | 0,82 | ns |
| Error | 417 | 1462,91 | 3,51 | | | |
| Total | 479 | 4822,26 | | | | |
| CV | 6,11% | | | | | |

*: 5% significant; ***: significant at 1%; ns: not significant

# RESULTS AND DISCUSSION

Table 3 - Zinc concentration in the grains of different wheat genotypes harvested in Passo Fundo - 2013

| Classificação | Genótipo | Média Zn (mg kg$^{-1}$) | | Classificação | Genótipo | Média Zn (mg kg$^{-1}$) | |
|---|---|---|---|---|---|---|---|
| 1 | BRS 331 | 36,83 | a | 18 | Marfim | 29,91 | d |
| 2 | TBIO Seleto | 34,21 | b | 19 | Jadeíte 11 | 29,84 | d |
| 3 | CD 1440 | 33,99 | b | 20 | TBIO Mestre | 29,09 | d |
| 4 | BRS Parrudo | 33,80 | b | 21 | Estrela Átria | 28,94 | d |
| 5 | BRS Guamirim | 33,14 | c | 22 | Fundacep Horizonte | 28,87 | d |
| 6 | JF 90 | 32,77 | c | 23 | Fundacep 52 | 28,13 | e |
| 7 | Fundacep Raízes | 32,76 | c | 24 | Campeiro | 27,94 | e |
| 8 | TEC Vigore | 32,61 | c | 25 | TBIO Itaipu | 27,51 | e |
| 9 | TBIO Alvorada | 32,19 | c | 26 | TBIO Sinuelo | 27,50 | e |
| 10 | Topázio | 32,04 | c | 27 | Quartzo | 27,48 | e |
| 11 | CD 1550 | 32,01 | c | 28 | TBIO Iguaçú | 27,47 | e |
| 12 | BRS 327 | 31,88 | c | 29 | Fundacep Bravo | 27,23 | e |
| 13 | BRS 328 | 31,74 | c | 30 | Mirante | 25,77 | e |
| 14 | TBIO Tibagi | 31,38 | c | | Média geral | 30,66 | |
| 15 | TEC Frontale | 30,94 | c | | C.V. | 6,42 % | |
| 16 | TBIO Pioneiro | 30,90 | c | | | | |
| 17 | Ametista | 30,19 | d | | | | |

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# RESULTS AND DISCUSSION

Table 3 - Zinc concentration in the grains of different wheat genotypes harvested in Passo Fundo - 2013

| Classification | Genotype | Zn (mg kg$^{-1}$) | |
|---|---|---|---|
| 1 | BRS 331 | 36,83 | a |
| 2 | TBIO Seleto | 34,21 | b |
| 3 | CD 1440 | 33,99 | b |
| 4 | BRS Parrudo | 33,80 | b |
| 5 | BRS Guamirim | 33,14 | c |
| 6 | JF 90 | 32,77 | c |
| 7 | Fundacep Raízes | 32,76 | c |
| 8 | TEC Vigore | 32,61 | c |
| 9 | TBIO Alvorada | 32,19 | c |
| 10 | Topázio | 32,04 | c |
| 11 | CD 1550 | 32,01 | c |
| 12 | BRS 327 | 31,88 | c |
| 13 | BRS 328 | 31,74 | c |
| 14 | TBIO Tibagi | 31,38 | c |
| 15 | TEC Frontale | 30,94 | c |
| 16 | TBIO Pioneiro | 30,90 | c |
| 17 | Ametista | 30,19 | d |
| 18 | Marfim | 29,91 | d |
| 19 | Jadeíte 11 | 29,84 | d |
| 20 | TBIO Mestre | 29,09 | d |
| 21 | Estrela Átria | 28,94 | d |
| 22 | Fundacep Horizonte | 28,87 | d |
| 23 | Fundacep 52 | 28,13 | e |
| 24 | Campeiro | 27,94 | e |
| 25 | TBIO Itaipu | 27,51 | e |
| 26 | TBIO Sinuelo | 27,50 | e |
| 27 | Quartzo | 27,48 | e |
| 28 | TBIO Iguaçú | 27,47 | e |
| 29 | Fundacep Bravo | 27,23 | e |
| 30 | Mirante | 25,77 | e |
| | Média geral | 30,66 | |
| | C.V. | 6,42 % | |

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# RESULTS AND DISCUSSION

Table 3 - Zinc concentration in the grains of different wheat genotypes harvested in Passo Fundo - 2013

| Classificação | Genótipo | Média Zn (mg kg$^{-1}$) | |
|---|---|---|---|
| 1 | BRS 331 | 36,83 | a |
| 2 | TBIO Seleto | 34,21 | b |
| 3 | CD 1440 | 33,99 | b |
| 4 | BRS Parrudo | 33,80 | b |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 15 | TEC Frontale | 30,94 | c |
| 16 | TBIO Pioneiro | 30,90 | c |
| 17 | Ametista | 30,19 | d |
| 22 | Fundacep Horizonte | 28,87 | d |
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| 24 | Campeiro | 27,94 | e |
| 25 | TBIO Itaipu | 27,51 | e |
| 26 | TBIO Sinuelo | 27,50 | e |
| 27 | Quartzo | 27,48 | e |
| 28 | TBIO Iguaçú | 27,47 | e |
| 29 | Fundacep Bravo | 27,23 | e |
| 30 | Mirante | 25,77 | e |
| | Média geral | 30,66 | |
| | C.V. | 6,42 % | |

**1,17% seeds disp.**

**$\overline{X}$=34,71 mg kg$^{-1}$**

**26,7% superior**

**72% seeds disp.**

**$\overline{X}$= 27,38 mg kg$^{-1}$**

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# RESULTS AND DISCUSSION

- Correlation between Fe e Zn:
  - r= 0,684 ***
- Genotypes with high levels of Fe or Zn have high probability of presenting high values of Zn and Fe, respectively.
- Correlation between Fe e Zn: Graham et al., (1999), Cakmak et al. (2004), Moraes et al., (2012);

# RESULTS AND DISCUSSION

**HARVEST METHOD:**

**Manually (handmade)**
**or**
**Mechanized (by machine)?**

# RESULTS AND DISCUSSION

Table 6 – Average of Iron concentration in grains of different genotypes of wheat harvested manually and mechanized, in Passo Fundo - 2013

| Classification | Harvest method | Average Fe (mg $kg^{-1}$) |
|---|---|---|
| 1 | Mechanized | 33,42 a |
| 2 | Manual | 33,28 a |

Means followed by the same letter do not differ significantly by the Tukey test at the 1% level of error probability.

# RESULTS AND DISCUSSION

Table 7 – Average of Zinc concentration in grains of different genotypes of wheat harvested manually and mechanized, in Passo Fundo - 2013

| Classification | Harvest method | Average Zn (mg $kg^{-1}$) |
|---|---|---|
| 1 | Mechanized | 30,68 a |
| 2 | Manual | 30,63 a |

Means followed by the same letter do not differ significantly by the Tukey test at the 1% level of error probability.

# RESULTS AND DISCUSSION

- The results disagree with the sampling protocols for micronutrient analysis of the HarvestPlus Biofortification Program (STANGOULIS & SISON, 2008);
- The mechanized harvest will allow to evaluate a greater number of genotypes, having the same human resources and in similar time;
- The new protocols are still in development;

# CONCLUSIONS

- The cultivars BRS Parrudo and BRS 331 presented the highest concentrations of Fe and Zn, respectively;
- None of the cultivars reaches the minimum concentration to be considered a biofortified cultivar using FAO scores;
- Grain harvesting methods, manual and mechanized, do not cause significant variation in Fe and Zn concentrations in wheat grains.

# Results - 2015

# Iron and Zinc concentration in grains of wheat genotypes in four environments in Paraná - 2015

Biff et al.

# RESULTS AND DISCUSSION
## Iron concentration

Table 1 - Analysis of Variance (ANOVA) for genotype and local factors, and interaction between genotype and local in Fe concentrations of different wheat genotypes - 2016

| Source | DF | SS | SM | F | P | |
|---|---|---|---|---|---|---|
| **Blocks** | **4** | **47,12** | **11,78** | **5,59** | **0,0011** | **** |
| **Main effects** | | | | | | |
| **Genotype** | **6** | **417,68** | **69,61** | **33,03** | **0,0000** | ***** |
| **Local** | **3** | **3,61** | **1,20** | **0,57** | **0,6370** | **ns** |
| **Interaction** | | | | | | |
| **Genótipo x Local** | **18** | **163,98** | **9,11** | **4,32** | **0,0001** | ***** |
| **Error** | **41** | **86,38** | **2,11** | | | |
| **Total** | **69** | **1086,23** | | | | |
| **CV 3,64 %** | | | | | | |

# RESULTS AND DISCUSSION
## Iron Concentration

Table 3. Concentration of zinc in grains harvested in four counties of Paraná in 2015

| Classificação | Genótipo | Média Fe (mg $kg^{-1}$) | |
|---|---|---|---|
| 1 | BRS Sanhaço | 43,28 | a |
| 2 | WT 12025 | 42,75 | a |
| 3 | WT 13086 | 40,05 | b |
| 4 | WT 13061 | 39,50 | b |
| 5 | WT 13007 | 39,46 | b |
| 6 | BRS Graúna | 39,20 | b |
| 7 | BRS Sabiá | 35,02 | c |
| | Média geral | 40,0 | |
| | C.V. | 3,64 % | |

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# RESULTS AND DISCUSSION
## Iron Concentration

Table 3. Concentration of iron in grains harvested in four counties of Paraná in 2015

| Classificação | Local | Média Fe (mg $kg^{-1}$) |
|---|---|---|
| 1 | Mauá da Serra | 41,81 a |
| 2 | Londrina | 41,55 a |
| 3 | Ponta Grossa | 38,83 b |
| 4 | Cruzmaltina | 35,71 c |
| | Média geral | 40,0 |
| | C.V. | 3,64 % |

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# RESULTS AND DISCUSSION
## Zinc Concentration

Table 4 - Analysis of Variance (ANOVA) for genotype and local factors, and interaction between genotype and local, in Zinc concentrations of different wheat genotypes - 2016

| Source | DF | SS | SM | F | P | |
|---|---|---|---|---|---|---|
| **Blocks** | 4 | 512,13 | 128,03 | 38,90 | 0 | *** |
| **Main effects** | | | | | | |
| **Genotype** | 6 | 357,73 | 59,62 | 18,12 | 0 | *** |
| **Local** | 3 | 39,37 | 13,12 | 3,99 | 0,0140 | * |
| **Interaction** | | | | | | |
| **Genotype x Local** | 18 | 290,14 | 16,12 | 4,89 | 0 | *** |
| **Error** | 41 | 134,92 | 3,29 | | | |
| **Total** | 69 | 4618,89 | | | | |
| **CV 6,30 %** | | | | | | |

# RESULTS AND DISCUSSION
## Zinc Concentration

Table 3. Concentration of zinc in grains harvested in four counties of Paraná in 2015

| Classification | Genotype | Average Zn (mg kg $^{-1}$) | |
|---|---|---|---|
| 1 | WT 13061 | 32,19 a | |
| 2 | BRS Graúna | 31,57 ab | |
| 3 | WT 13086 | 28,75 | bc |
| 4 | WT 11167 | 28,55 | c |
| 5 | WT 12025 | 28,39 | c |
| 6 | WT 13007 | 27,78 | c |
| 7 | BRS Sabiá | 24,01 | d |
| | Average | 28,75 | |
| | C.V. | 6,30 % | |

# RESULTS AND DISCUSSION
## Zinc Concentration

Table 3. Concentration of zinc in grains harvested in four counties of Paraná in 2015

| Classificação | Local | Média Zn (mg $kg^{-1}$) |
|---|---|---|
| 1 | Londrina | 36.86 a |
| 2 | Ponta Grossa | 27.89 b |
| 3 | Cruzmaltina | 22.94 c |
| 4 | Mauá da Serra | 19.20 d |
| | Média geral | 28,75 |
| | C.V. | 6,30 % |

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# Results - 2015

# Iron and zinc concentration in wheat cultivars from the South Brazilian recommended list - 2015

Scheeren et al.

# Material and Methods

Sowing date: 30/05/2015, in the experimental field of Embrapa Wheat;

Genotypes: 29 cultivars from the recommended list of wheat cultivars from Rio Grande do Sul State - 2015;

Trial with 3 replicates;

Plots: 2.4 $m^2$, with 330 seeds $m^{-2}$.

# Material and Methods

- The plots were harvested mechanically;
- Samples of 50 g of grains were separated from each plot and sent to the laboratory of EMBRAPA – CTAA, to determine the concentration of Fe and Zn;
- Determination of Fe and Zn concentrations by “X-ray Fluorescence Spectroscopy”;
- The results were submitted to Analysis of Variance and Skott-Knott's test, (5%);

# Results and discussion

**Tabela 1: Iron concentration in grains of cultivars from the Southern Brazilian List of wheat cultivars. Passo Fundo/RS, 2015.**

| Rank | Cultivar | mean | |
|---|---|---|---|
| 1 | BRS Parrudo | 44.01 | a |
| 2 | TBIO Mestre | 38.91 | b |
| 3 | Jadeíte | 38.89 | b |
| 4 | TBIO Tibaji | 37.56 | bc |
| 5 | Topázio | 37.50 | bc |
| 6 | BRS Reponte | 36.93 | bc |
| 7 | BRS Guamirim | 36.77 | bcd |
| 8 | FCEP Cristalino | 36.76 | bcd |
| 9 | TbIO Sintonia | 36.54 | bcde |
| 10 | TEC Vigore | 36.19 | bcde |
| 11 | CD 1440 | 36.00 | bcdef |
| 12 | Marfim | 35.24 | bcdef |
| 13 | BRS 296 | 34.98 | bcdef |
| 14 | BRS 327 | 34.97 | bcdef |
| 15 | FCEP Raízes | 34.96 | bcdef |
| 16 | LG Prisma | 34.82 | bcdef |
| 17 | FCEP Horizonte | 34.52 | bcdef |
| 18 | TBIO Pioneiro | 34.50 | bcdef |
| 19 | FCEP 50 | 33.87 | cdef |
| 20 | BRS 179 | 33.55 | cdef |
| 21 | Vaqueano | 33.42 | cdef |
| 22 | TEC 10 | 33.27 | cdefg |
| 23 | FCEP Campo Real | 33.04 | cdefg |
| 24 | BRS Marcante | 33.00 | cdefg |
| 25 | TEC Frontale | 32.93 | cdefg |
| 26 | Celebra | 32.24 | defg |
| 27 | Estrela Átria | 32.06 | efg |
| 28 | Ametista | 31.46 | fg |
| 29 | ORS 25 | 28.90 | g |
| | Mean | 35,09 | |
| | C.V. | 6.58 % | |

# RESULTS and DISCUSSION

- **For Fe, the highest value was 44 mg $kg^{-1}$, in the cultivar BRS Parrudo;**
- ***The minimun concentration of Fe to be considered biofortified is 52 mg $kg^{-1}$ (BOUIS, et al.,).***
- ***But considering***

| Iron | |
|---|---|
| Baseline | 28 ppm |
| Target Increment | 14 ppm |
| Target Level in Crop | 42 ppm |
| **Zinc** | |
| Baseline | 26 ppm |
| Target Increment | 13 ppm |
| Target Level in Crop | 39 ppm |

- **Only the cultivar BRS Parrudo can be considered as Biofortified fo Iron;**

# Results and discussion

**Tabela 2: Zinc concentration in grains of cultivars from the Southern Brazilian List of wheat cultivars. Passo Fundo/RS, 2015.**

| Rank | Cultivar | Mean | |
|---|---|---|---|
| 1 | Vaqueano | 36.64 | a |
| 2 | TBIO Tibagi | 36.06 | a |
| 3 | BRS Parrudo | 35.61 | ab |
| 4 | BRS Guamirim | 35.61 | abc |
| 5 | BRS 327 | 34.19 | abc |
| 6 | Marfim | 33.48 | abc |
| 7 | Estrela Átria | 33.39 | abc |
| 8 | Jadeíte | 32.59 | abcd |
| 9 | FCEP 50 | 32.55 | abcd |
| 10 | CD 1440 | 32.47 | abcd |
| 11 | BRS Marcante | 32.27 | abcd |
| 12 | FCEP Campo Real | 31.81 | abcd |
| 13 | BRS 179 | 30.69 | bcde |
| 14 | TEC Vigore | 30.68 | bcde |
| 15 | FCEP Raízes | 30.57 | bcde |
| 16 | FCEP Cristalino | 30.55 | bcde |
| 17 | Topázio | 30.54 | bcde |
| 18 | FCEP Horizonte | 30.38 | cde |
| 19 | BRS Reponte | 30.29 | cde |
| 20 | TBIO Pioneiro | 30.28 | cde |
| 21 | TBIO Mestre | 30.05 | cde |
| 22 | BRS 296 | 29.90 | cde |
| 23 | Celebra | 29.84 | cde |
| 24 | TEC Frontale | 29.62 | cde |
| 25 | TEC 10 | 27.95 | def |
| 26 | Ametista | 27.69 | def |
| 27 | TBIO Sintonia | 26.08 | ef |
| 28 | ORS 25 | 24.68 | f |
| 29 | LG Prisma | 23.82 | f |
| | Mean | 31.04 | |
| | C.V. | 8.12% | |

# RESULTS and DISCUSSION

***The minimun concentration of Zinc to be considered biofortified***

**41 mg $kg^{-1}$ (BOUIS, et al.,).**

| | |
|---|---|
| **Iron** | |
| Baseline | 28 ppm |
| Target Increment | 14 ppm |
| Target Level in Crop | 42 ppm |
| **Zinc** | |
| Baseline | 26 ppm |
| Target Increment | 13 ppm |
| Target Level in Crop | 39 ppm |

**None cultivar can be considered as Biofortified for Zinc;**

# Iron and zinc concentration in wheat (Triticum aestivum L.) grains of the Rio Grande do Sul State list of recommended Wheat Cultivars - 2016

**Prezotto et al.**

# Material and Methods

The plots were harvested mechanically;

Samples of 50 g of grains were separated from each plot and sent to the laboratory of EMBRAPA – CTAA, to determine the concentration of Fe and Zn;

Determination of Fe and Zn concentrations by “X-ray Fluorescence Spectroscopy”;

The results were submitted to Analysis of Variance and Skott-Knott's test, (5%);

# Results and Discussion

Table 2: Concentration of Iron in grains of wheat cultivars of the EECT-RS in 2016.

| Rank | Cultivar | Average Fe (mg kg$^{-1}$) | Rank | Cultivar | Average Fe (mg kg$^{-1}$) |
|---|---|---|---|---|---|
| 1 | BRS 194 | 39,77 a | 16 | TBIO NOBLE | 25,90 b |
| 2 | BRS 327 | 35,20 a | 17 | BRS MARCANTE | 25,63 b |
| 3 | CD1440 | 35,07 a | 18 | TBIO PIONEIRO | 25,13 b |
| 4 | JADEÍTE | 34,37 a | 19 | CD 1805 | 25,07 b |
| 5 | BRS PARRUDO | 33,07 a | 20 | MARFIM | 24,87 b |
| 6 | LG PRISMA | 31,90 a | 21 | TBIO SINTONIA | 24,87 b |
| 7 | LG ORO | 31,60 a | 22 | TBIO SOSSEGO | 24,70 b |
| 8 | TOPAZIO | 30,27 a | 23 | TBIO IGUAÇU | 24,53 b |
| 9 | BRS REPONTE | 29,93 a | 24 | TBIO TIBAGI | 22,97 b |
| 10 | TBIO MESTRE | 29,57 a | 25 | CD 1104 | 22,83 b |
| 11 | ORS 1401 | 28,70 b | 26 | TBIO TORUK | 22,33 b |
| 12 | BRS 331 | 27,93 b | 27 | ESPORÃO | 22,00 b |
| 13 | TBIO SINUELO | 27,53 b | 28 | TBIO ITAIPU | 19,30 b |
| 14 | AMETISTA | 26,67 b | | Média geral | **27,79** |
| 15 | CAMPEIRO | 26,30 b | | C.V. | 13,40% |

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# Results and Discussion

Table 2: Concentration of Zn in grains of wheat cultivars of the EECT-RS in 2016

| Rank | Cultivar | Average Zn (mg $kg^{-1}$) | Rank | Cultivar | Average Zn (mg $kg^{-1}$) |
|---|---|---|---|---|---|
| 1 | BRS MARCANTE | 32,67 a | 16 | CD 1104 | 27,00 a |
| 2 | BRS PARRUDO | 31,53 a | 17 | TBIO SINUELO | 26,70 a |
| 3 | BRS 331 | 31,37 a | 18 | LG PRISMA | 26,13 b |
| 4 | JADEÍTE | 31,17 a | 19 | TBIO TIBAGI | 26,00 b |
| 5 | BRS 194 | 30,77 a | 20 | TBIO IGAÇU | 25,73 b |
| 6 | BRS 327 | 29,27 a | 21 | TBIO SOSSEGO | 25,50 b |
| 7 | TOPAZIO | 28,90 a | 22 | MARFIM | 25,47 b |
| 8 | CD 1440 | 28,67 a | 23 | TBIO TORUK | 25,40 b |
| 9 | TBIO NOBLE | 28,37 a | 24 | BRS REPONTE | 23,63 b |
| 10 | AMETISTA | 28,23 a | 25 | TBIO ITAIPU | 23,37 b |
| 11 | TBIO PIONEIRO | 27,93 a | 26 | TBIO SINTONIA | 23,30 b |
| 12 | ORS 1401 | 27,83 a | 27 | CAMPEIRO | 20,57 b |
| 13 | LG ORO | 27,77 a | 28 | ESPORÃO | 20,50 b |
| 14 | TBIO MESTRE | 27,00 a | | Média geral | **27,06** |
| 15 | CD 1805 | 27,00 a | | C.V. | 12,13% |

Means followed by the same letter do not differ significantly by the Scott-Knott test at the 5% probability level of error

# RESULTS and DISCUSSION

**None cultivar can be considered as Biofortified for Iron or Zinc;**

| | |
|---|---|
| **Iron** | |
| Baseline | 28 ppm |
| Target Increment | 14 ppm |
| Target Level in Crop | 42 ppm |
| **Zinc** | |
| Baseline | 26 ppm |
| Target Increment | 13 ppm |
| Target Level in Crop | 39 ppm |

# General conclusions

- ✓ The previously results showed that levels above 40 ppm of iron and zinc are high for the evaluated material.
- ✓ Only the cultivar BRS Parrudo can be considered as Biofortified for Iron;
- ✓ None cultivar presented the minimum required Zinc concentration.

- **Future:**

- Brazilian cultivars can be improved to be more nutritious, with higher concentrations of Fe and Zn in the grains;
- Molecular markers will be identified and used to create wheat cultivars with higher concentrations of Fe and Zn in the grains;
- Genetic association studies are in development (BR/UK project);
- Biparental populations are in the end of development ($F_6$/$F_7$);
- Breeding program for Iron and Zinc will continue…


BRS Parrudo


BRS Parrudo

# Many thanks!

Thanks to all colleagues of wheat breeding team of Embrapa

# Thanks for your attention!

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