Presentation developed by
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During the Master in Boron fertilization in Maize Crops at Universidade Federal do Parana – Brazil

FEDERAL UNIVERSITY OF PARANA STATE
Division of Agricultural Sciences
Department of Soil Science and Agricultural Engineering
Master in Soil Science

Lesson developed by Fabiano Silvestrin and presented to Post Graduation at Federal University of Parana
Boron and Plant Nutrition

Curitiba
2011

BORON

MINERAL NUTRITION OF PLANTS.

FABIANO SILVESTRIN

BORON IN SOIL

- Unlike other micronutrients, B has predominance in sedimentary rocks.

BORON IN SOIL

- The Boron concentration in the soil is variable, ranging between 7 and 80 $mg.kg^{-1}$, with average value of 10 $mg.kg^{-1}$ (KRAUSKOPF, 1972).

- According to Jackson (1970), the total concentration of boron in the soil can vary between 4 and 98 $mg.dm^{-3}$, and for regions where there is the presence of clay soils and moisture, the content of that nutrient in the soil is between 30 and 60 $mg.dm^{-3}$ and in sandy soils variation occurs between 2 and 6 $mg.dm^{-3}$.

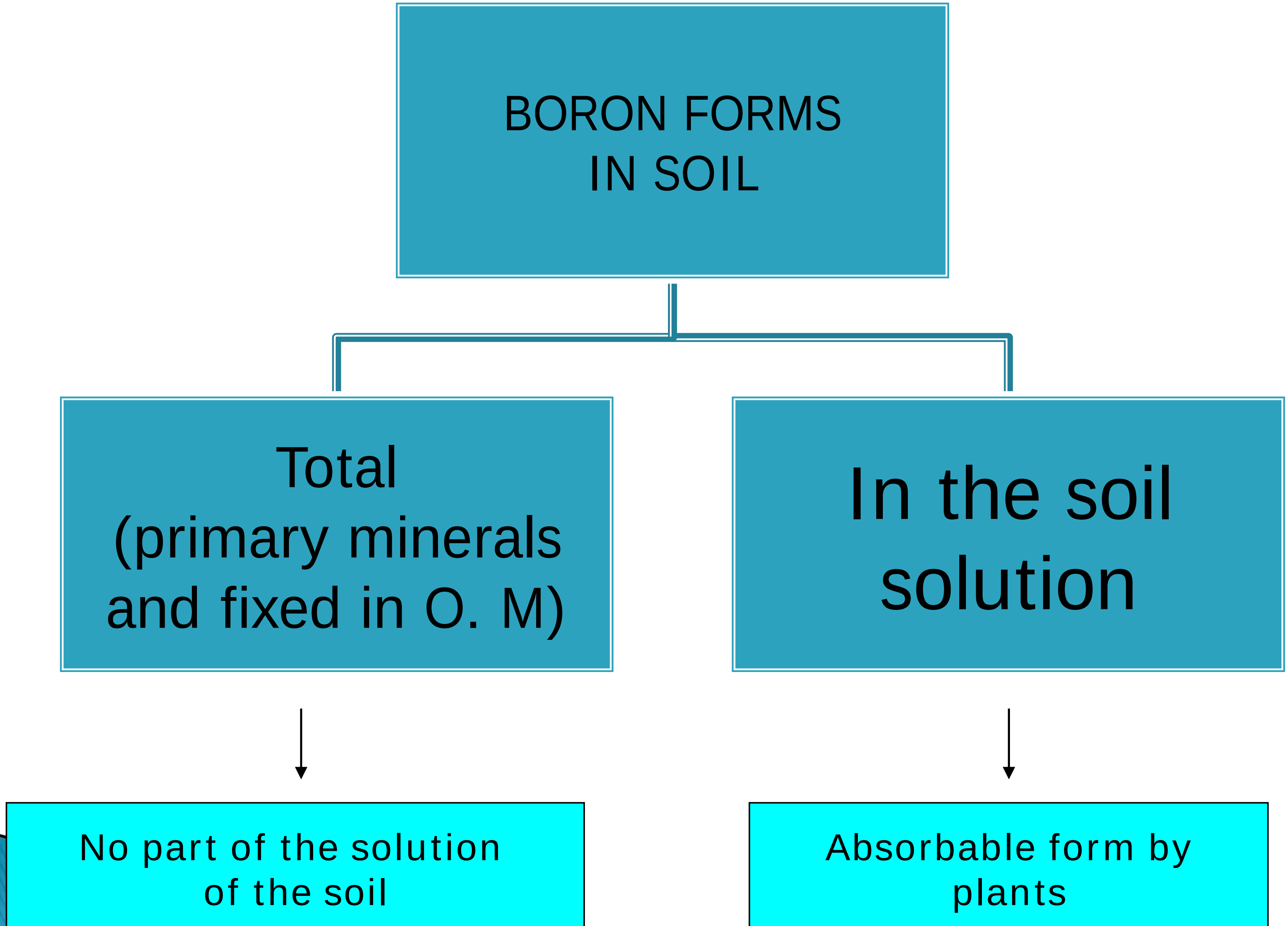
BORON IN SOIL

- A factor of concern among researchers for boron is the existence of a narrow band between the limits of its sufficient concentration in soil and the toxic level for most plants (Motta *et la*., 2007, GOLDBERG, 1997).

BORON IN SOIL

- In most agricultural soils, B is in the form of boric acid (H_3BO_3), which is a weak acid.

BORON IN SOIL



BORON IN THE SOIL. (Effects of pH)

BORON IN SOIL SOLUTION

H_3BO_3

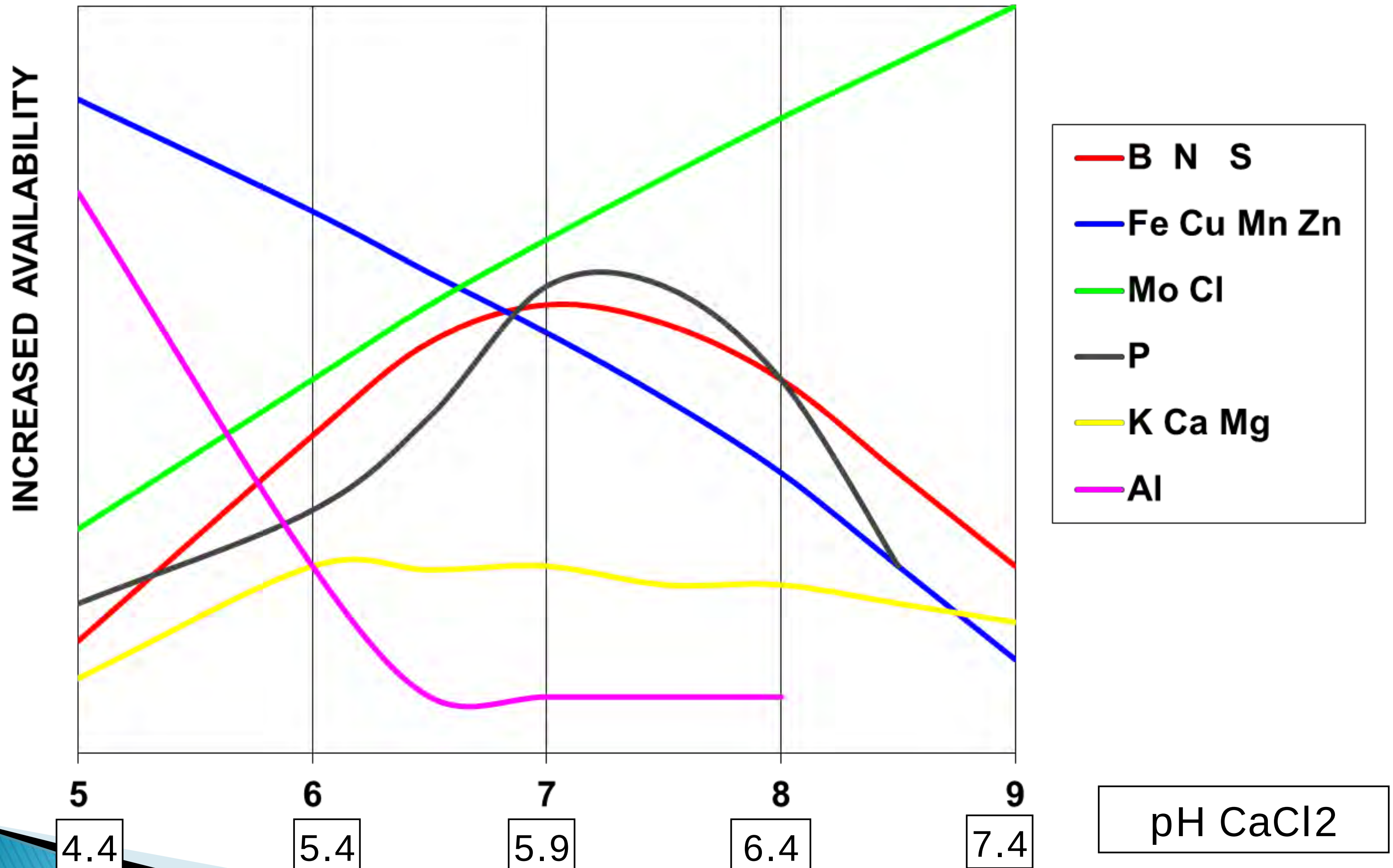
($pH < 7.0$)

$H_4BO_4^-$

from pH 7.0

The greatest availability of B in the soil is in the pH range between 5.0 and 7.0. pH range between 5.0 and 7.0

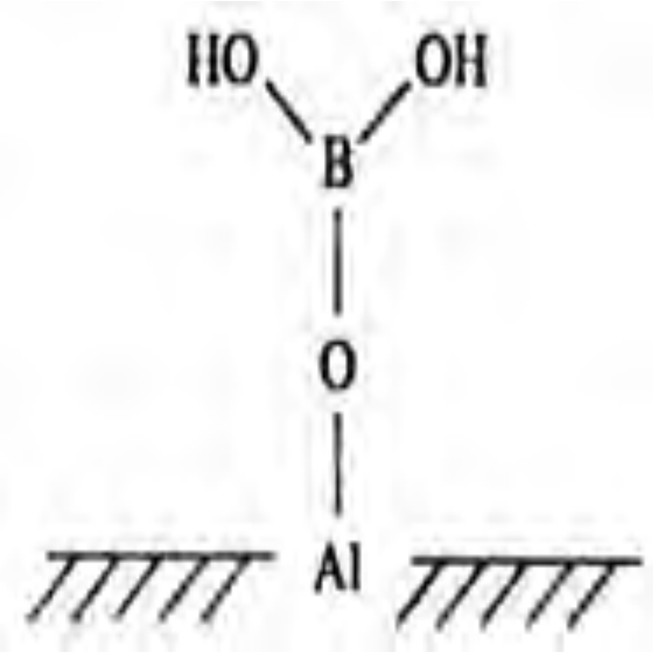
AVAILABLE NUTRIENTS IN EACH VARIATION OF pH.



Source: Adapted Lopes, 1989.

BORON IN SOIL (ADSORBTION)

- The oxides and hydroxides of Fe and Al adsorb large amounts of B, especially in the pH range between 6.0 and 9.0.



Adsorption of boron in the soil.

- The adsorption increases with increasing pH, temperature, content of the adsorbent materials and with decreasing soil moisture (GOLDBERG, 1993).

- The oxides and hydroxides comprise the clay fraction of the soils; therefore, the greater the clay content of the soil, the greater the adsorption of B (Toner IV & Sparks, 1995).

Adsorption of boron in the soil.

Boron Adsorption the pH oxides 6.0

20 X GREATER

Al OXIDES

Fe OXIDES

Adsorption of boron by clays.

BORON ADSORPTION IN SOIL

ILITA

ARGILA 2:1

>

MONTMORILONITA

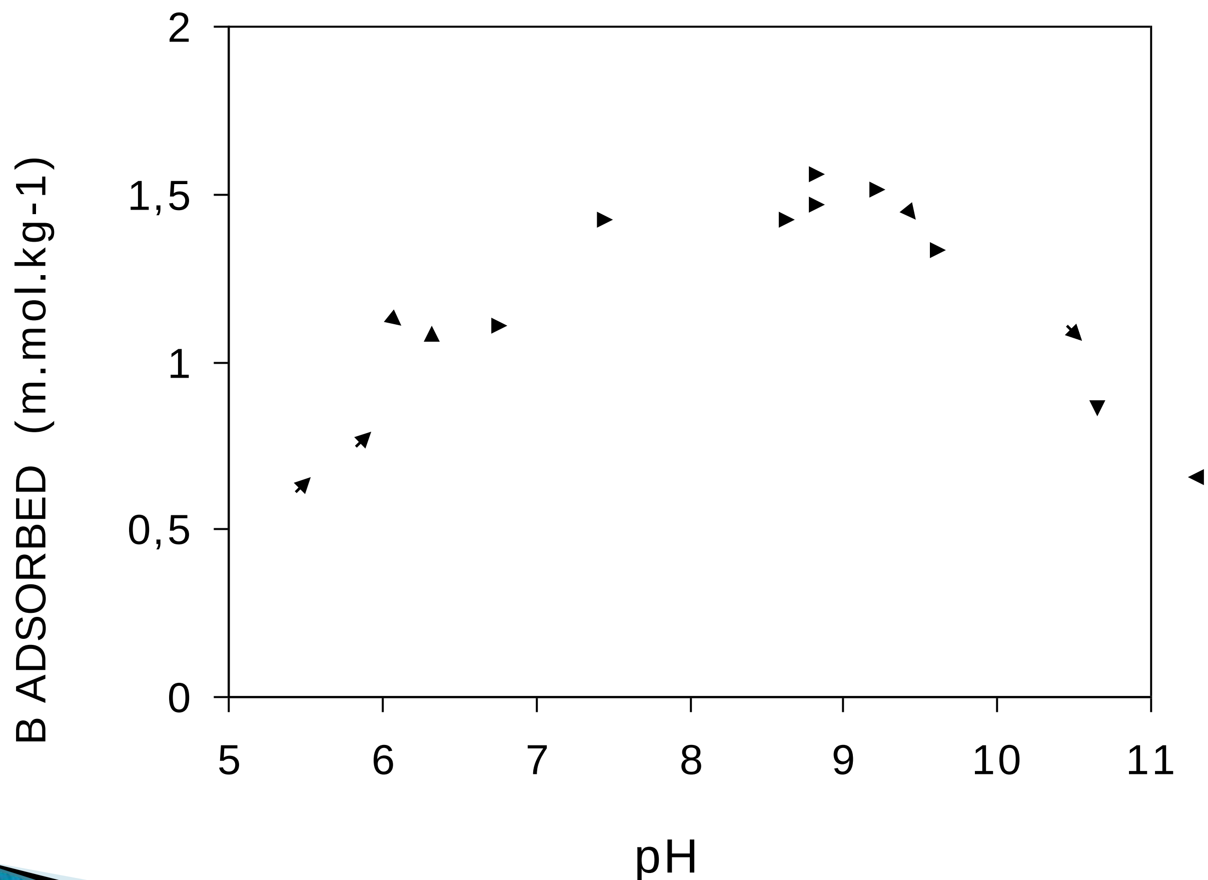
ARGILA 2:1

>

CAULINITA

ARGILA 1:1

Adsorption of boron to iron oxide in solutions containing 5 mg B.L^{-1} (GOLDBERG & GLAUBIG, 1985).



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BORON IN THE SOIL. (Under drought conditions).

TWO REASONS DROUGHT CONDITIONS ACCELERATE APPEARANCE BY THE DEFICIENCY B:

- MINOR DECOMPOSITION OF ORGANIC MATTER SOIL
- TRANSPORT OF THE B SOIL IS REDUCED (MASS FLOW).

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BORON IN THE SOIL. (ROOT GROWTH).

- LeNOBLE et al. (1993), LUKASZEWSKI & BLEVINS (1996) and Cabrera (2006) found that, in dicotyledons, boron provided the root development even under conditions of toxic aluminum.

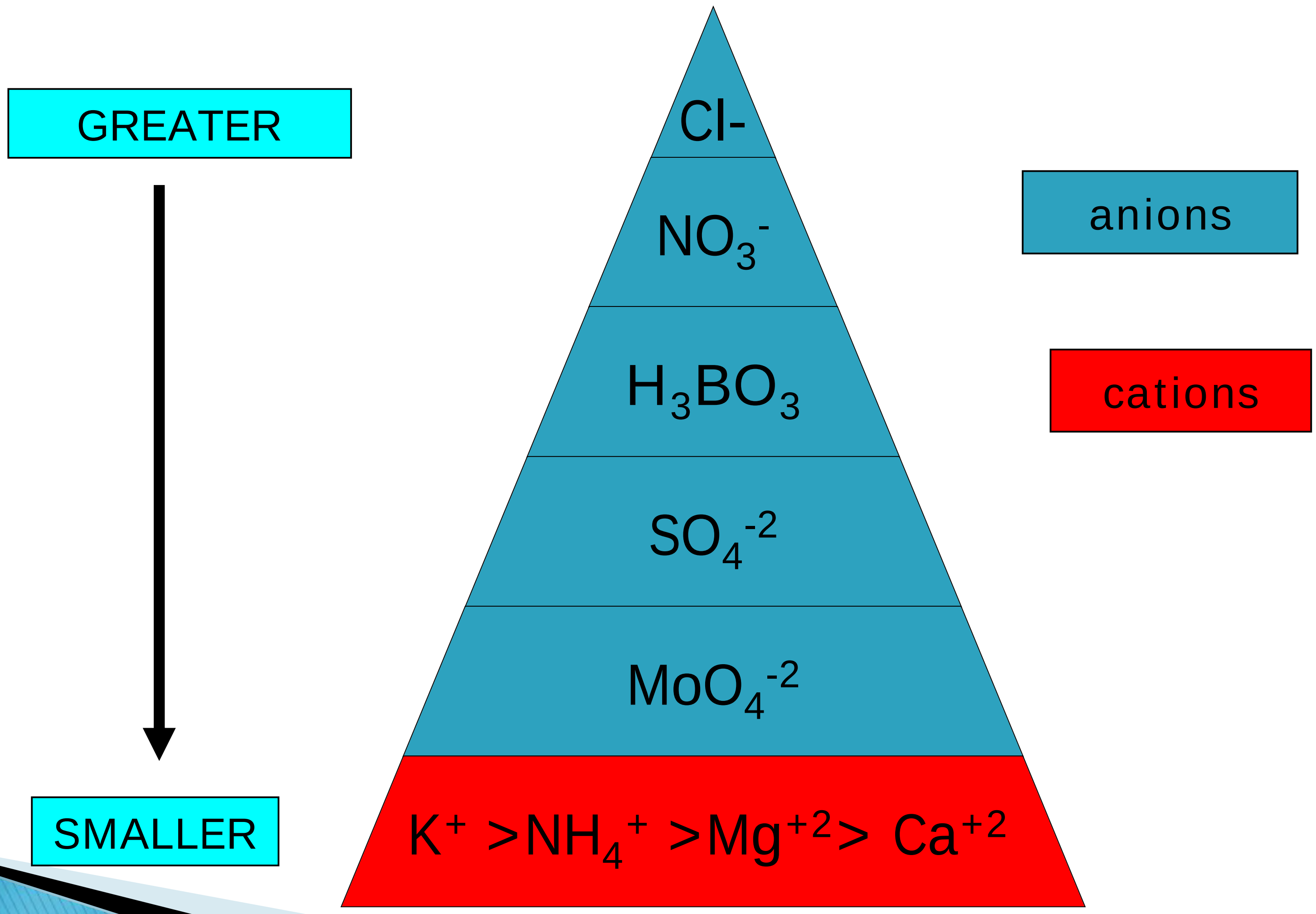
- The second paper explained the phenomenon by the increased production of ascorbate in plants supplied with boron. Plants with boron deficiency recovered the root development with the addition of ascorbate to the medium.

BORON LEACHING IN THE SOIL.

- The availability of boron in the soils is directly related to soil textural class.

- Under conditions of predominantly sandy soils, associated with high rainfall, there is a high degree of B losses by leaching, decreasing its availability in the soil (ABREU; LOPES; SANTOS, 2007).

NUTRIENT LEACHING.



Adapted Vitti, 2009.

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LEACHING

ANIONS $(Cl^{-} > NO^{3-} > H_3BO_3 > SO4^{-2} > MoO4^{-2})$

CATIONS $(K^{+} > NH^{4+} > Mg^{+2} > Ca^{+2})$

MECHANISMS OF NUTRIENT ABSORPTION:

ROOT INTERCEPTION: Ca^{+2} , Mg^{+2}

MASS FLOW: $Cl^{-} > H_3BO_3 > NO_{3-} > SO4^{-2} > MO4^{-2} >$

$Na^{+} > K^{+} > NH^{4+} > Mg^{+2} > Ca^{+2}$

SPREADING: $H_2PO_{4-} > Cu^{+2} > Mn^{+2} > Zn^{+2} > Fe^{+2} > K^{+}$

A RECOMMENDATION OF FERTILIZING CAN BE BASED IN:
MASS FLOW: GROOVE FERTLIZING OR IN COVERAGE.
SPREADING: IN PLANTING (SOWING), ALWAYS NEAR
THE ROOT SYSTEM, IMPROVING THE EFFICIENCY OF FERTILIZATION,
MAINLY FOR MICRONUTRIENTS (Cu,Fe,Mn e Zn).

Adapted Vitti, 2009

BORON IN THE SOIL.

- Extraction of Boron in soils by hot water was suggested by Berger and Truog in 1939 and it is today considered one of the best methods to use.

- For the compound H_3BO_3, the diffusion value for boron in water is 10.1×10^{-6} $cm2.s^{-1}$ (ELLIS et alii, 1983) and in the soil SULAIMAN & KAY (1972) found an average of $2.5\ 10^{-6}$ $cm2.s^{-1}$.

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BORON IN THE PLANT

- B is absorbed by the plant in the form of boric acid (H_3BO_3) and/or borate ion ($H_4BO_4^-$).
- B is immobile in plants and translocated mainly through the xylem, having a very limited mobility in the phloem.
- The accumulation of B occurs in the older leaves, specially at the tips and margins.

BORON IN THE PLANT

- As a rule, boron is immobile in the phloem.
- Exceptions are plants that produce polyols – as sorbitol, mannitol, dulcitol – which complex boron, making it mobile in the phloem, as it occurs in almond, apple and nectarine tree (Potafós, June 2000).
- B deficiencies are observed in younger leaves.

FUNCTIONS OF BORON ON THE PLANT.

- Transport of sugars.
- Summary of cell wall, lignification, cell wall structure.
- Carbohydrate metabolism, RNA metabolism.
- Respiration and metabolism of AIA, phenolic metabolism, ascorbate metabolism and plasmatic membrane integrity.
- Ripening of flowers and pollen tube growth.

FUNCTIONS OF BORON ON THE PLANT.

- Boron is involved in absorption and metabolism of cations, especially Ca, in the formation of cell membrane pectine.

- Boron acts in the nitrogen metabolism and in the activity of hormones.

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BORON IN THE PLANT (INTERACTIONS WITH OTHER NUTRIENTS)

- The work of POWER & WOODS (1997) provides a lot of information related to boron, with great practical implication:
- The absorption of potassium increases in the presence of boron and it hardly occurs in its absence; or many cases of potassium deficiency may, in fact, be boron deficiency.
- Boron has an important role in the transport of P tjrough the membranes, and as in the case of K, many cases of P deficiency can actually reflect B deficiency.

BORON IN THE PLANT (INTERACTIONS WITH OTHER NUTRIENTS)

- B and Zn are essential for the optimal functioning of the ATPase and the plasmatic membrane redox systems; without B there can be a reduced efficiency and Zn and vice versa.

- The urease enzyme is inhibited by boric acid – a warning or explanation for cases of failures in the foliar application of urea along with boric acid.

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BORON IN THE PLANT

- The concentration of B in plants range between 12 and 50 mg kg^{-1} of dry weight of the tissue.
- For a good growth of most crops, B concentrations in the leaf tissue should be between 30 to 50 mg kg^{-1}.
- Deficient plants exhibit leaf concentrations less than 15 mg kg^{-1}. (Malavolta, 1980; Malavolta et al., 1989; Pais & Jones Junior, 1996; Furlani, 2004).

FOLIAR LEVELS OF BORON IN MAIZE.

- FOLIAR LEVELS OF BORON CONSIDERED TO BE IDEAL FOR MAIZE: VALUES BETWEEN 10 – 25 mg kg^{-1}. (EMBRAPA, 1999).

Extraction and export of Boron from some agricultural crops.

Crop	Extraction $g.t^{-1}$ of grain	Export $g.t^{-1}$ grain
Soybean	77	22
Corn	18.3	4.4
Wheat	19.9	2.9
Bean	66.3	13.3

ADAPTED PAULETTI, 2004

SYMPTOMS OF BORON DEFICIENCY IN PLANTS.

- Reduced growth and deformation in the zones of growth (in plants with B deficiency, the new cells are not differentiated).
- Decreased foliar surface with deformed, thickened, brittle and small leaves. They may exhibit chlorosis or even a more intense green color.
- Reduced root growth.
- Floral abortion.

SYMPTOMS OF BORON DEFICIENCY IN PLANTS.

- Cracks in branches, petioles and sometimes in the fruits.
- Decrease in chlorophyll concentration.
- Decrease in resistance to infections.
- Decreased activity of oxidizing enzymes (catalase, peroxidase and polyphenol oxidase).

Summary presentation of Master Degree

UNIVERSIDADE FEDERAL DO PARANA
Division of Agricultural Sciences
Department of Soil Science and Agricultural Engineering
Master in Soil Science

Fabiano Silvestrin

Application and determination of the critical levels of boron in maize

Advisor: Prof. Dr. Volnei Pauletti
Co-advisor: Prof. Dr. Antonio Carlos Vargas Motta

Curitiba
2011

INTRODUCTION

SOURCE: SILVESTRIN, 2009

Boron in soil

- Sand soils
B losses by leaching.

Toxicity

Limit **Close**

Deficiency

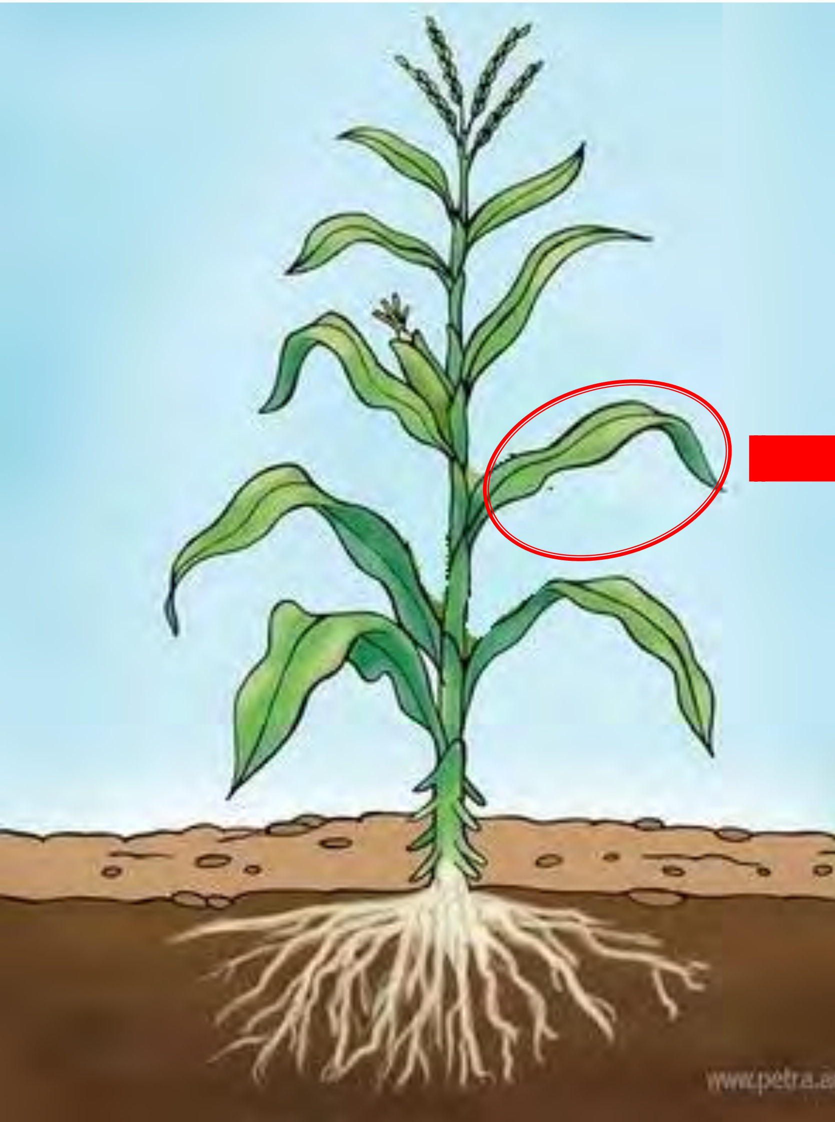
BORON IN THE PLANT

- Absorption: H_3BO_3 e $H_4BO_4^-$
- Immovable in most plants, translocated via the xylem.
- Accumulation of B occurs in older leaves, corners and edges

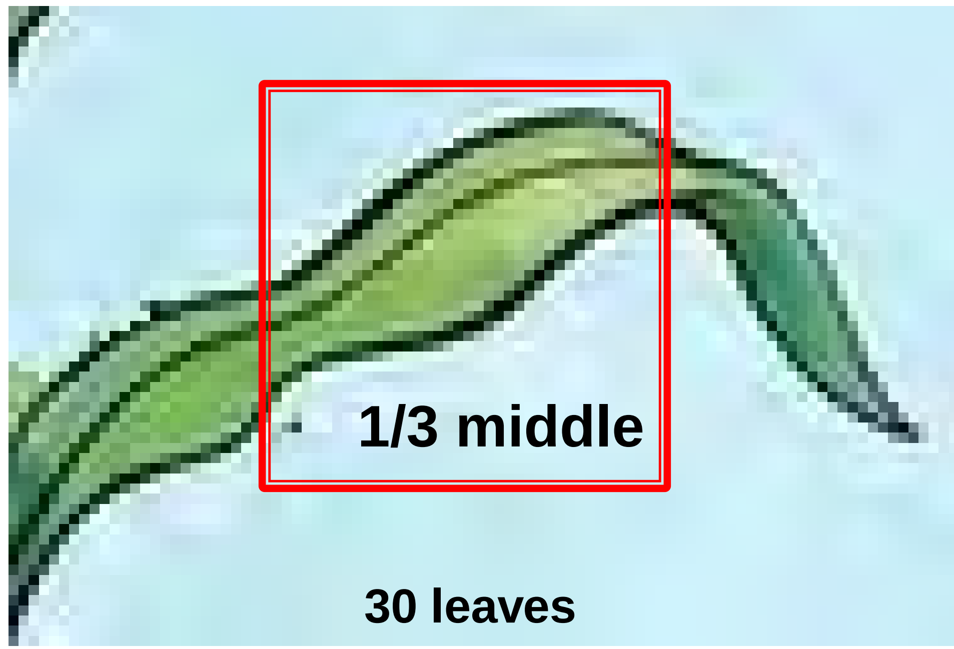
LEVELS OF BORON CONSIDERED SUFFICIENT IN FOLIAR TISSUE FOR A GOOD DEVELOPMENT OF MAIZE.

AUTHORS	Levels of B – mg kg^{-1}
RAIJ *et al.*, 1996	10 – 25
EMBRAPA, 2009	10 – 25
OLIVEIRA, 2002	10 – 25
MALAVOLTA *et al.*, 1997	15 – 20
REHM, 2002	6 – 40
LOPES, 1998	5 – 25

Recommendation of collection of leaf tissue for chemical analysis of boron



1st sheet below and opposite the spike



Malavolta et al., 1997; Oliveira, 2002; Pauletti, 2004

OBJECTIVES

SILVESTRIN, 2009.

GENERAL OBJECTIVE

- Check the response of maize crop to the application of increasing doses of boron and determination of critical levels of this nutrient in plants.

SPECIFIC OBJECTIVES

- Evaluate the effect of boron application on the productivity in maize crop
- Determine the critical levels of B in plants for maize crop
- Determine which part of the leaf or plant tissue best expresses the critical level of boron in the maize plant

ASSUMPTIONS

- Fertilization with boron increases productivity in maize crop.
- The different plant tissues analyzed should have different critical levels of boron for maize crop

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MATERIAL AND METHODS

SOURCE: SILVESTRIN, 2009.

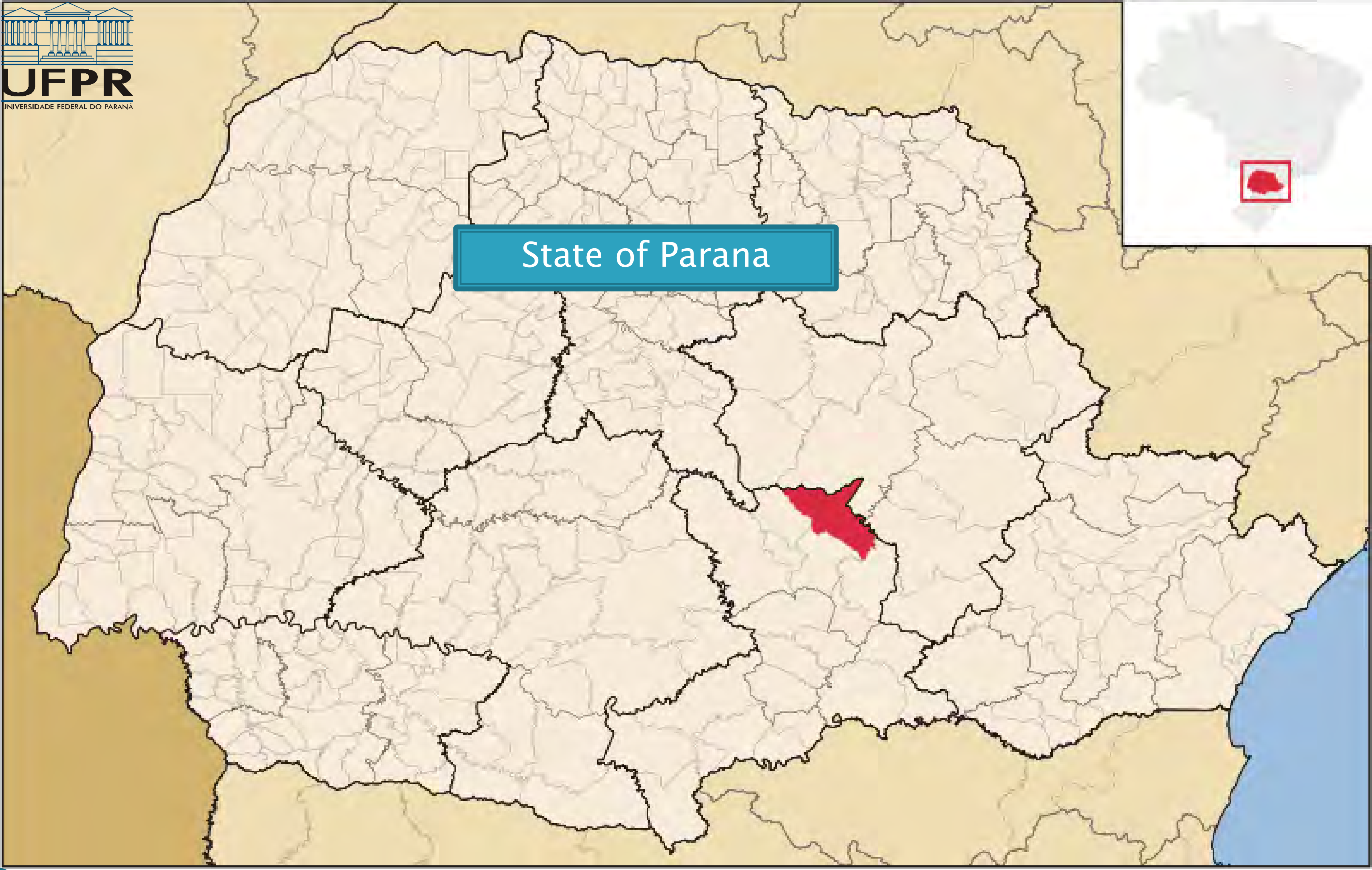
TWO EXPERIMENTS WERE PERFORMED:

- LATOSSOLO Bruno Dystrophic, medium texture (EMBRAPA, 2006).
- Ipiranga – Parana state
- Altitude of 905 meters
- 25°59'15.8" South and 50°41'54.9" West

CROP 2008/2009

- LATOSSOLO Vermelho Dystrophic, medium texture (EMBRAPA, 2006).
- Ipiranga – Parana state
- Altitude of 890 meters
- 25°01'43.6" South and 50°42'53.8" West

CROP 2009/2010



SOURCE:www.wikipedia.org,

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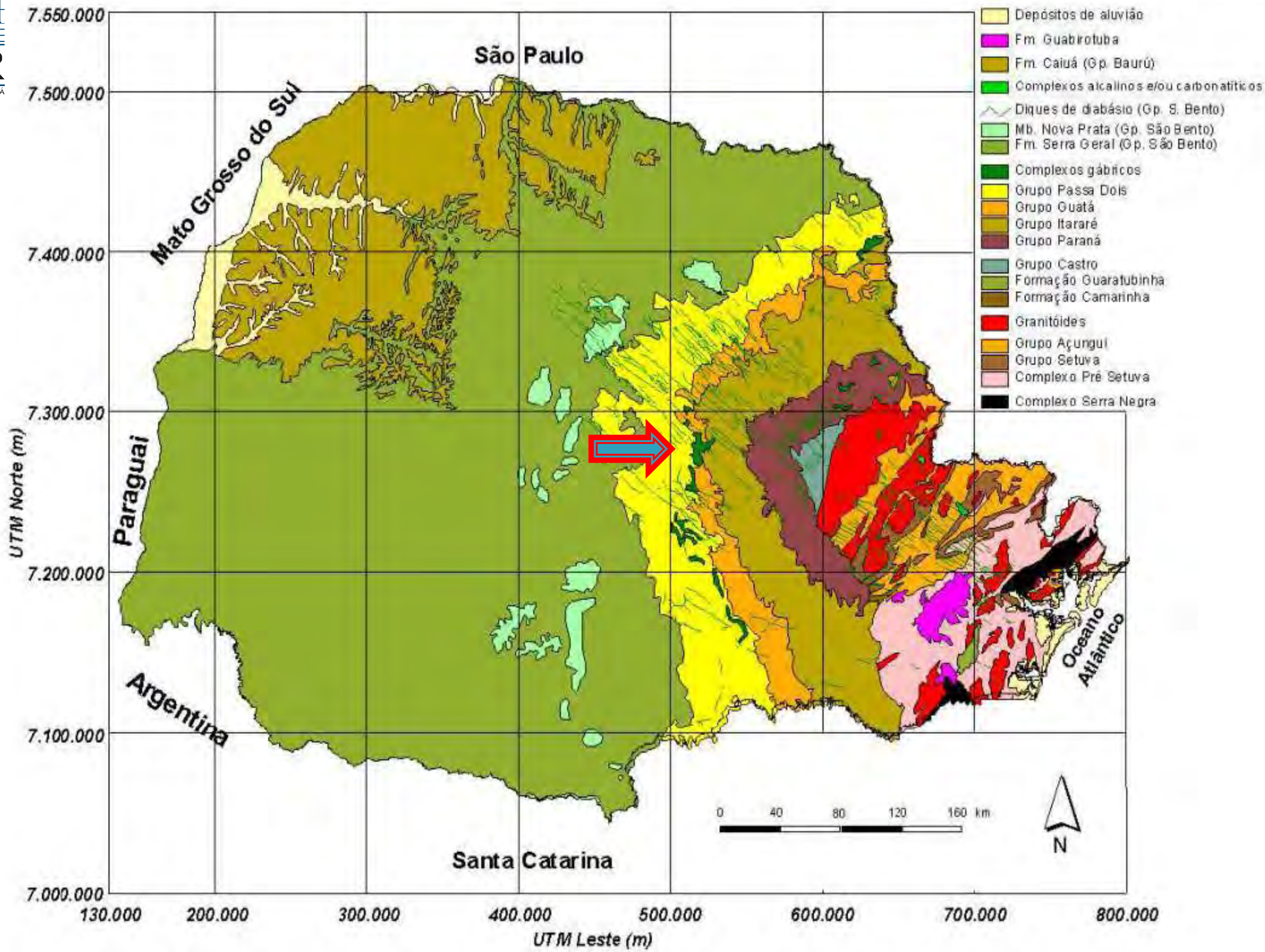
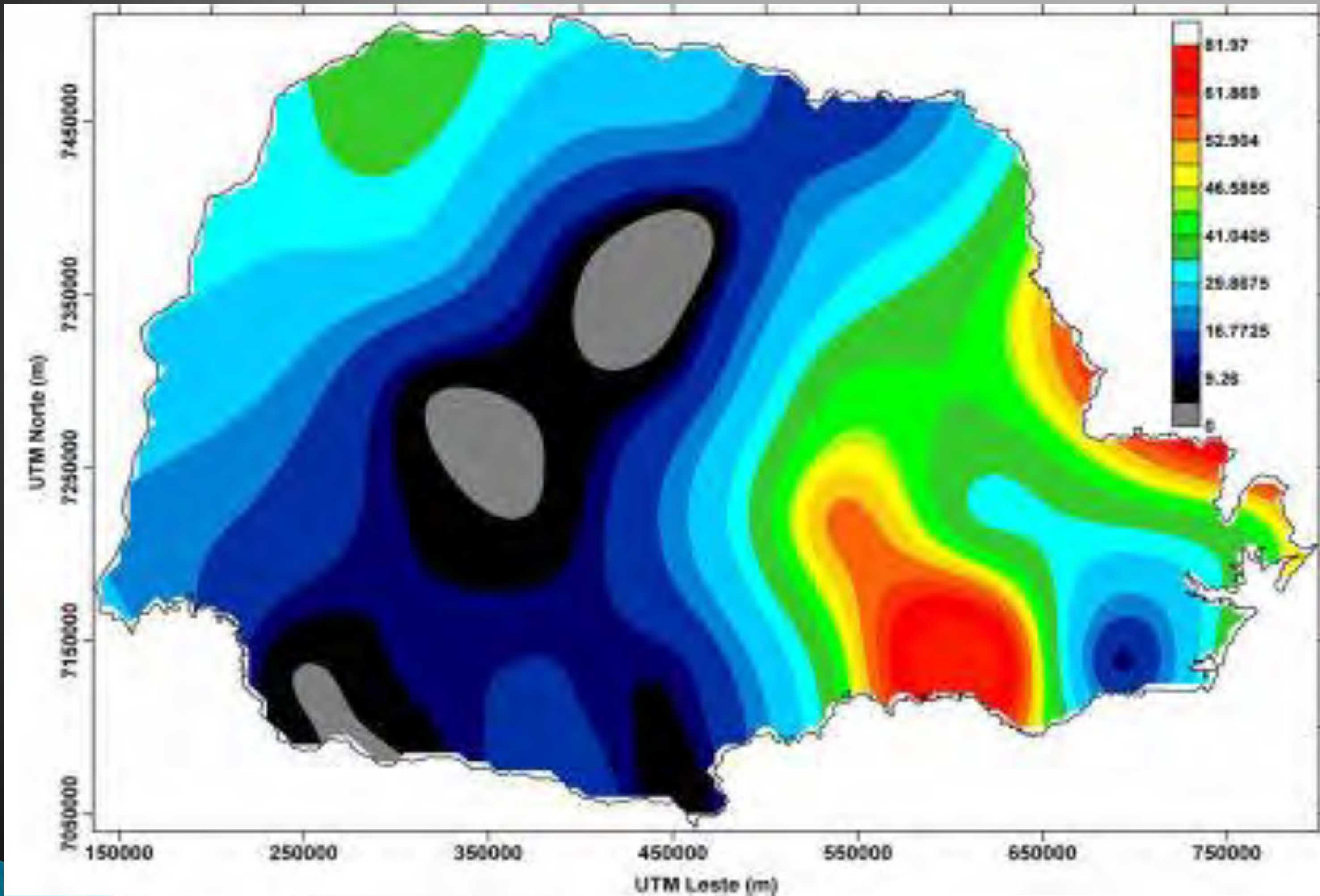
SOURCE: SILVESTRIN, 2009



SOURCE: MINEROPAR, 2009

Presence of Boron in soils of Parana State (Brazil)

Boron levels in the soil



High levels

Medium levels

Low levels

Source: Professor Ph.D Motta, Universidade Federal do Parana

PHYSICAL ANALYSIS OF SOILS– 0 to 20 cm

	Sand	Clay	Silt
Latossolo Bruno Dystrophic, medium texture. (crop 2008/09)	587 g Kg^{-1}	283 g Kg^{-1}	130 g Kg^{-1}
Latossolo Vermelho Dystrophic, medium texture. (crop 2009/10).	532 g Kg^{-1}	332 g Kg^{-1}	136 g Kg^{-1}

CHEMICAL ANALYSIS OF SOIL – 0 to 20 cm

	pH	P	K	Ca	Mg	Al	O. M.	B
	$CaCl_2$	mg dm^{-3}	mmolc dm^{-3}	mmolc dm^{-3}	mmolc dm^{-3}	mmolc dm^{-3}	g dm^{-3}	mg dm^{-3}
Latossolo Bruno Dystrophic	4.9	11	1.1	24	12	1.9	31.63	0.17
Latossolo Vermelho Dystrophic	5.1	14	1.4	29	14	0	22.17	0.19

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EXPERIMENTS: CROPS 2008/09 and 2009/10

- Hybrid: Pioneer 30P34
- Spacing between lines: 0.7 meters
- Seeds: 70.000 ha^{-1}
- Boron source: Boric Acid

EXPERIMENTS: CROPS 2008/09 and 2009/10

- Fertilization:
  - Planting: 320 kg ha^{-1} of NPK12-25-12
  - Broadcast: 165 kg ha^{-1} of urea (V4) and
    180 kg ha^{-1} of NPK 20-00-20 (V6)

- Totaling: 150 kg ha^{-1} de N, 80 kg ha^{-1} of P_2O_5 and 72 Kg ha^{-1} of K_2O

FACT SCHEME 2X6

TREATMENTS	
SEASON OF APPLICATION	DOSES OF BORON – Kg ha^{-1}
PLANTING (SEM) V6	0
	1
	2
	3
	4
	12

Boron source: H_3BO_3

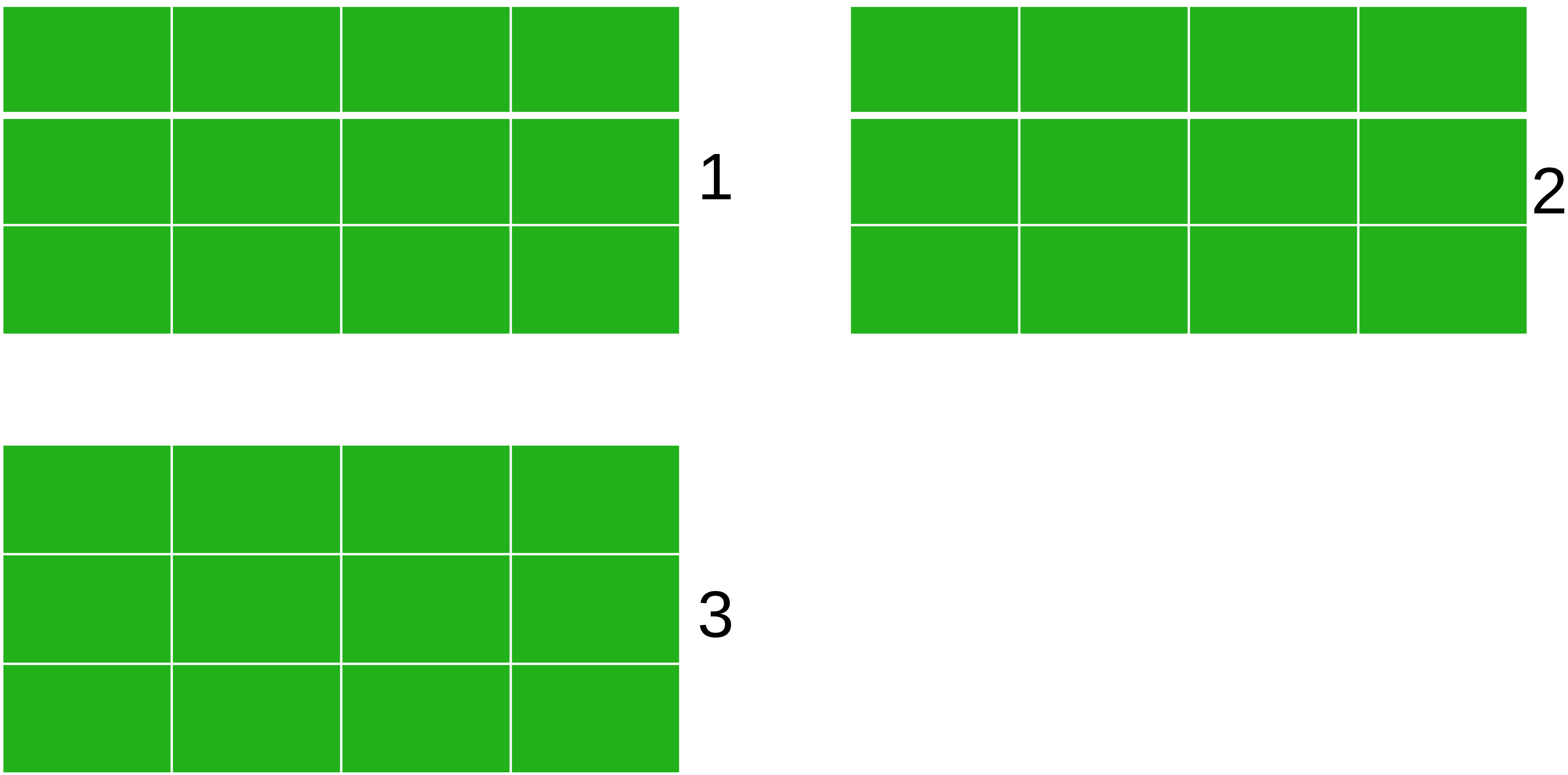
SEASONS OF APPLICATION OF BORON

FIRST APPLICATION:
PLANTING (SEM)

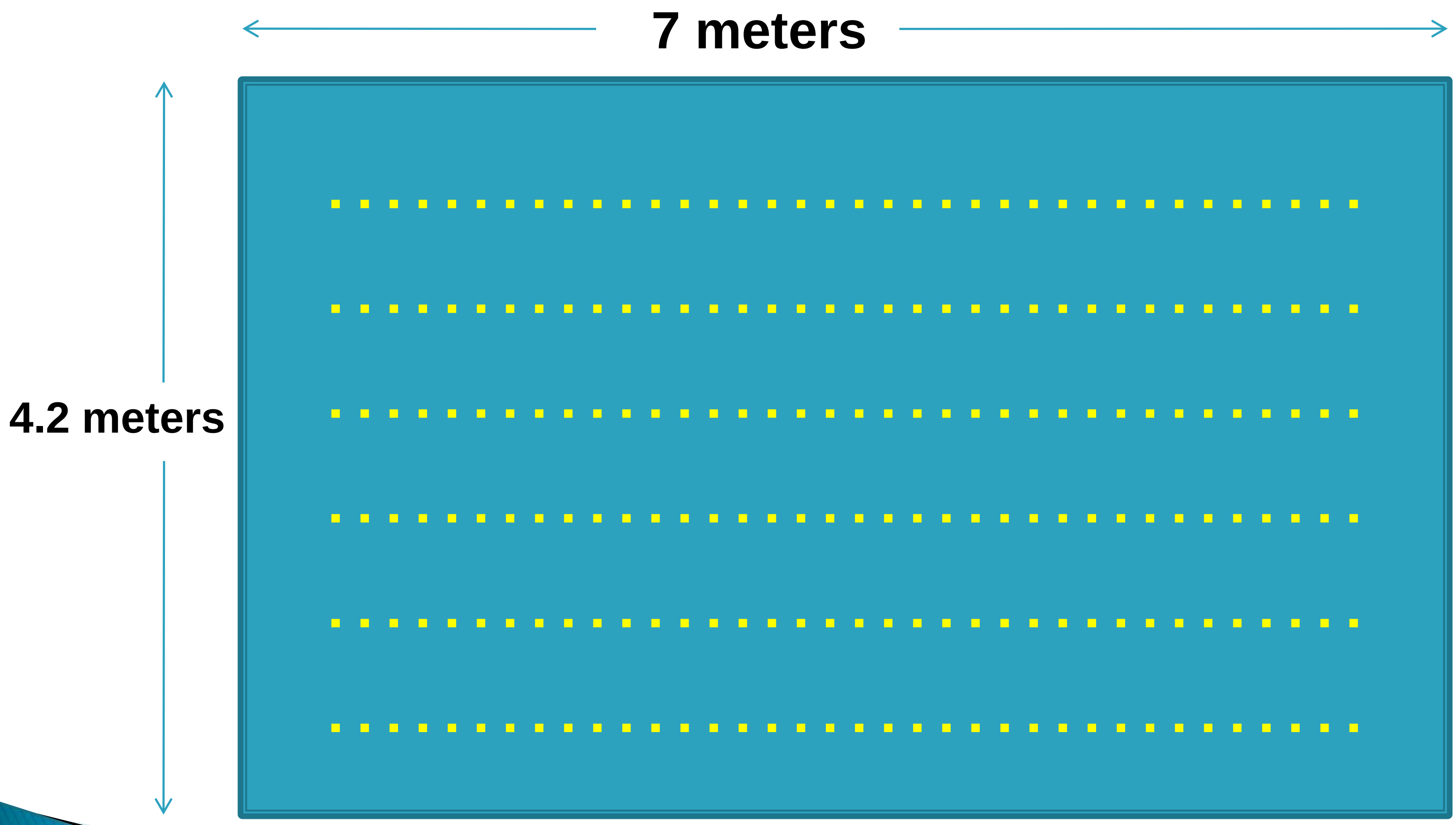
SECOND **APPLICATION**:
V6 STADIUM

SOURCE: EMBRAPA

Randomized blocks with 3 replications.



STATEMENT OF PORTION



SHARE: 29.4 m^2

ANALYSIS OF TISSUES – B

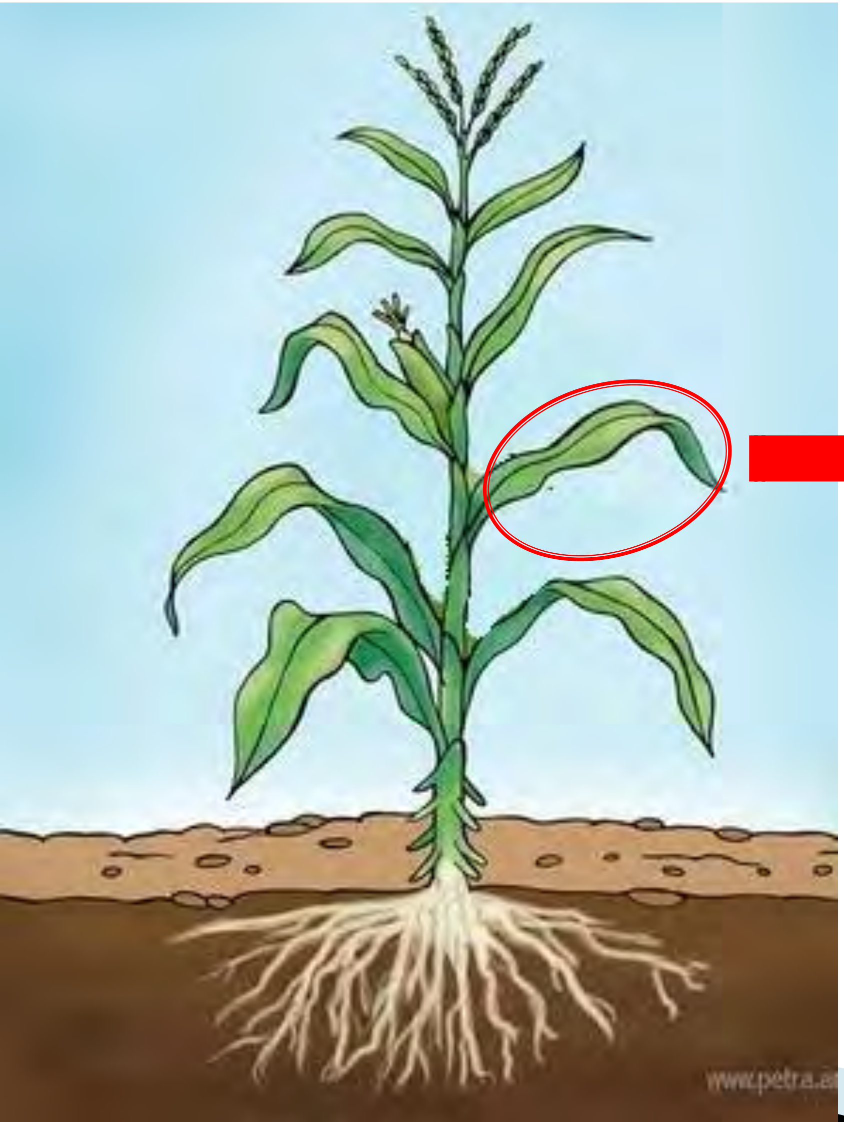
FIRST LEAF BELOW AND OPPOSITE THE COB

- 1/3 INFERIOR
- 1/3 MIDDLE
- 1/3 SUPERIOR
- WHOLE LEAF

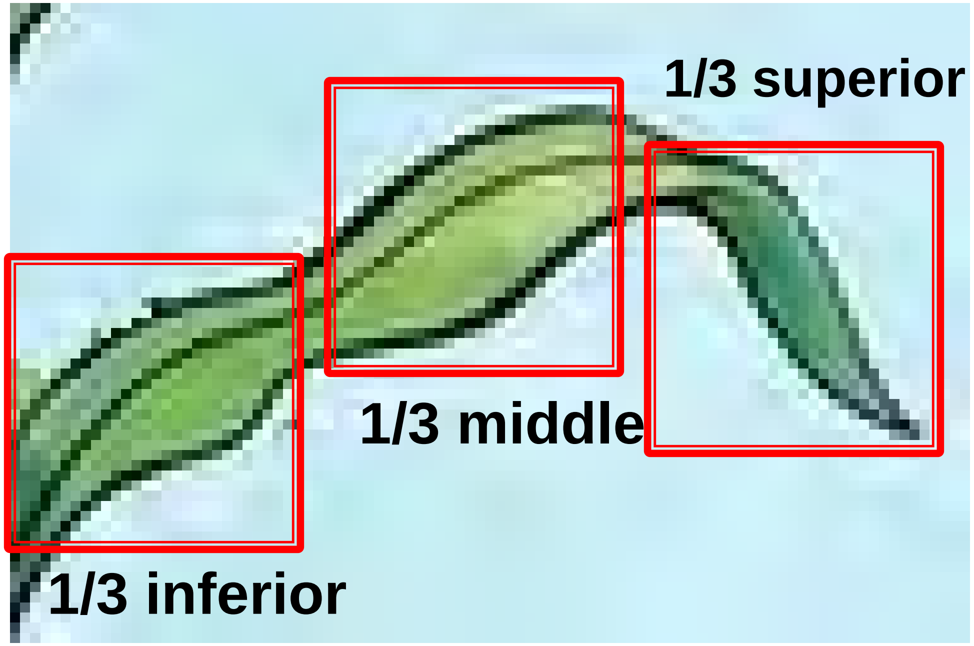
COB LEAF

FEMALE INFLORESCENCE

1st sheet below and opposite the spike

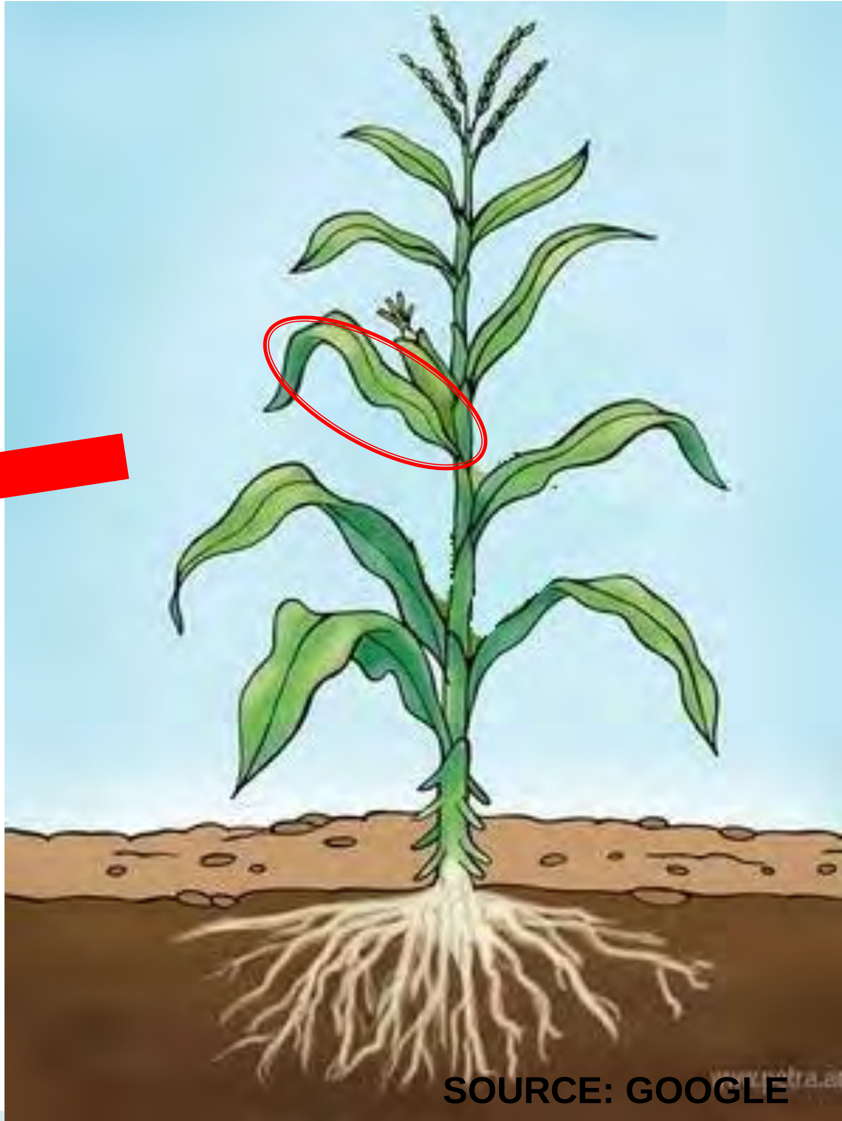


1st sheet below and opposite the spike

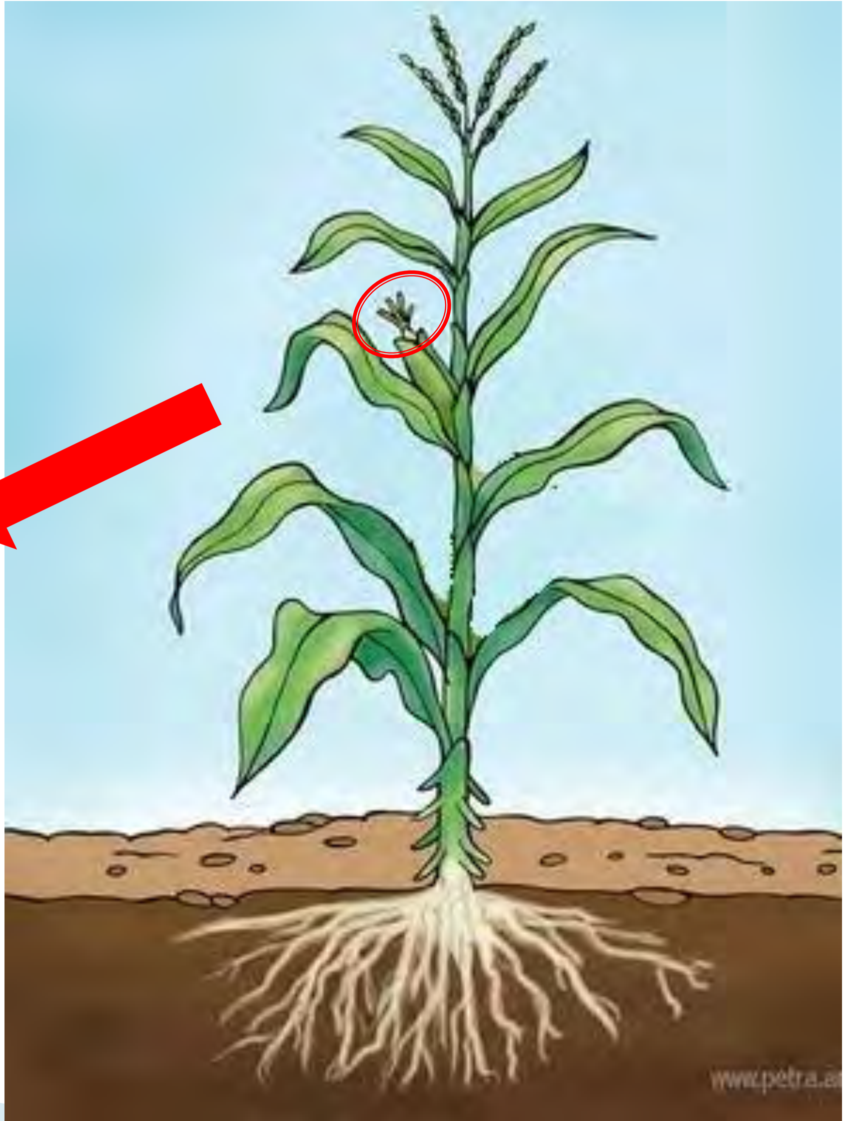


SOURCE: SILVESTRIN, 2009.

SPIKE LEAF
(collect for chemical analysis)



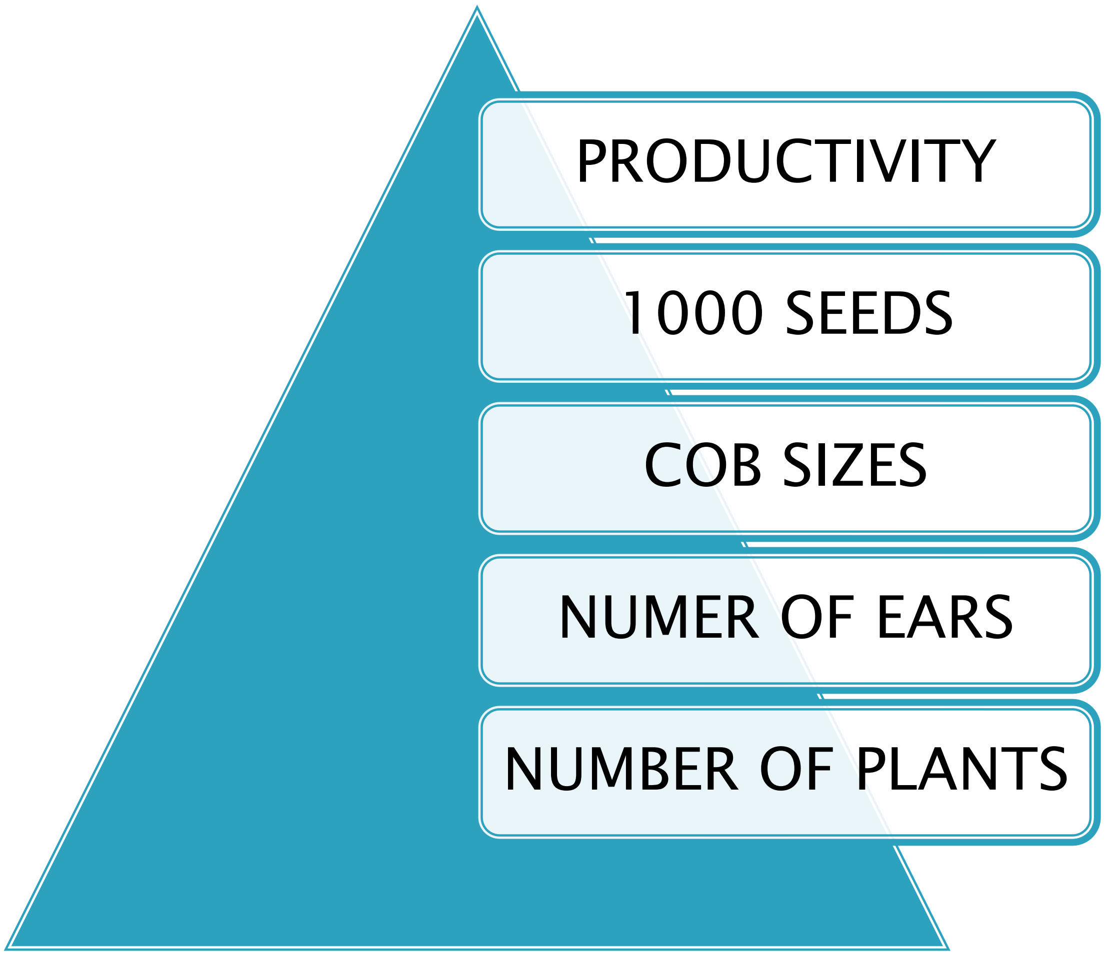
Female inflorescence of maize "spike hair"



SOURCE: SILVESTRIN, 2009

SOURCE: SILVESTRIN, 2009

YIELD COMPONENTS



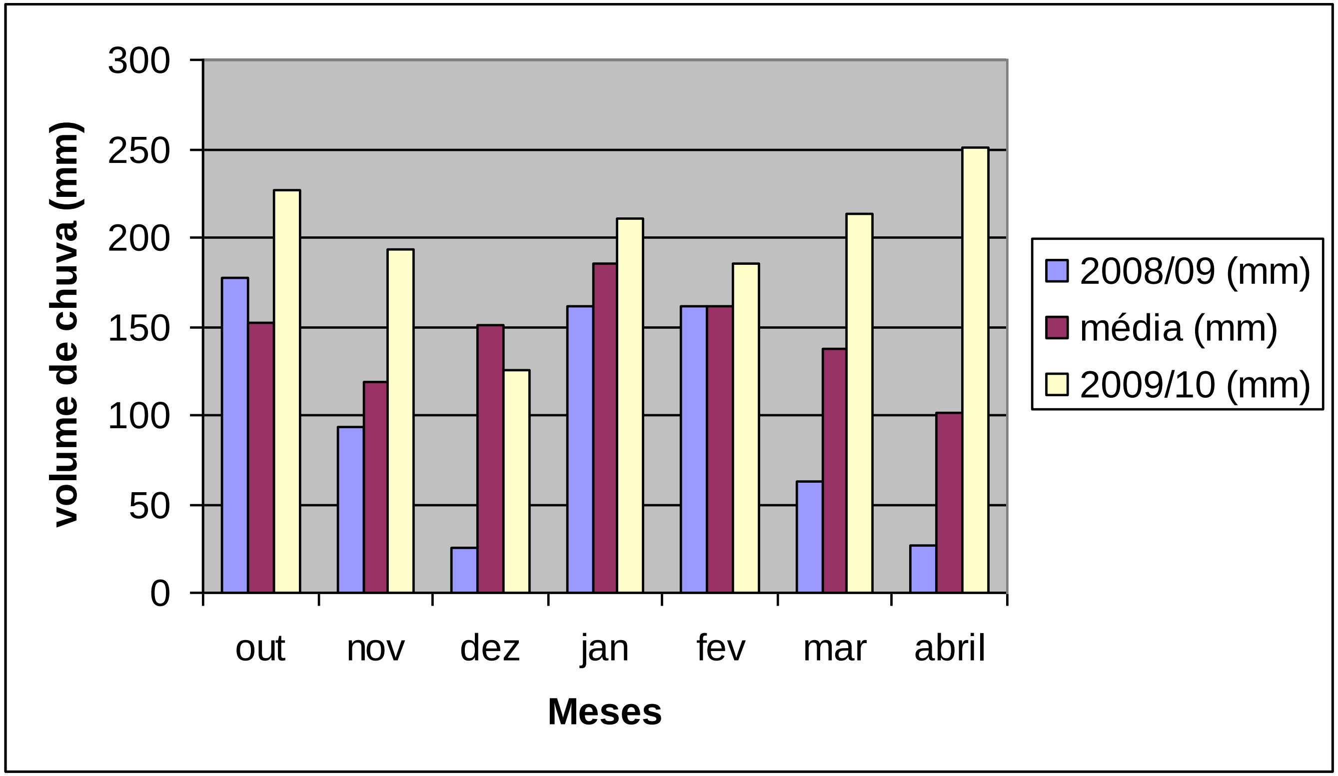
SOIL COLLECTION

(20 sub-samples per plot)

0 – 20 cm

20 – 40 cm

Rainfall between months from October to April of 2008/09 and 2009/10 seasons.



média=average
chuva=rain

SOURCE: Adapted IAPAR, 2010.

STATISTICAL ANALYSES

- The results were analyzed for normality by the Shapiro-WilK test.

- ANOVA
- (Significance of Contents 5%)

- For doses regression equations were adjusted using the mean polynomial of higher degree.

RESULTS AND DISCUSSION

Effect of season

Season	Yield		M.M.G		Plants		Spikes		Cob Size		B - Only 0-20 cm		B - Only 20-40 cm	
	kg ha^{-1}		g						cm		mg kg^{-1}			
2008_09														
Planting	8228	a	289.72	a	63672	a	59636	a	15.38	a	-		-	
V6	7769	a	286.12	a	63695	a	58916	a	15.34	a	-		-	
CV	9.11		3.37		3.05		4.69		3.65					
2009_10														
Planting	**8548**	a	347.17	a	**65928**	a	65061	a	**15.24**	a	0.22	b	0.23	b
V6	7576	b	345.39	a	62118	b	62066	a	14.76	b	**0.44**	a	**0.39**	a
CV	12.21		6.7		9.44		8.61		3.3		42.65		41.89	

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Effect of season

Season	BORON - TISSUE											
	Spike leaf		Below sheet		1/3 average		1/3 superior		1/3 inferior		Hair	
	mg kg^{-1}											
	2008_09											
Planting	11.33	a	12.75	a	8.76	a	20.48	b	11.02	b	17.99	a
V6	11.73	a	12.15	a	10.18	a	**22.66**	a	**11.53**	a	16.81	a
CV	28.33		51.21		35.6		13.29		11.83		21.94	
	2009_10											
Planting	7.74	b	10.12	a	8.40	b	10.83	b	7.99	b	23.31	a
V6	**9.65**	a	11.35	a	**10.49**	a	**13.86**	a	**9.69**	a	26.58	a
CV	28.4		31.73		20.52		23.15		22.04		21.58	

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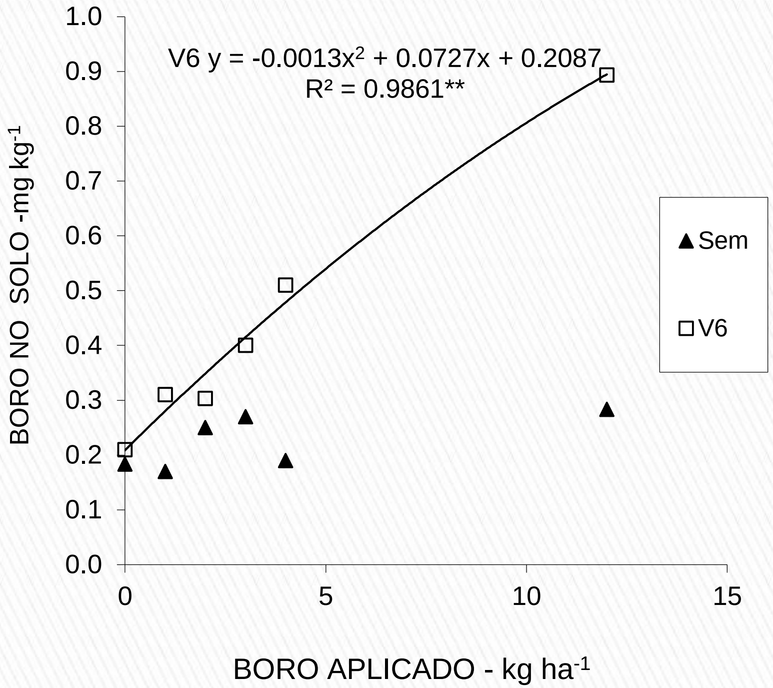
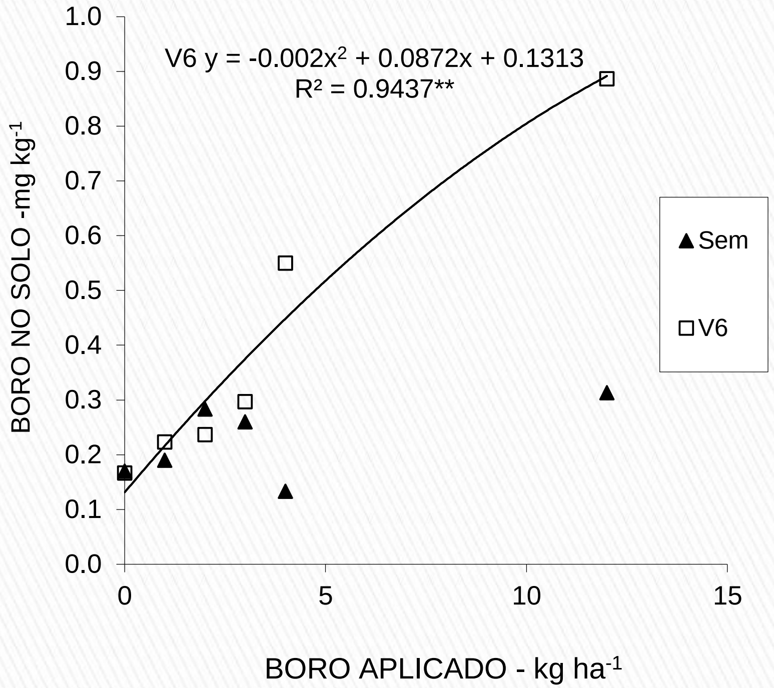
BORON CONCENTRATION IN THE SOIL "LATOSSOLO VERMELHO DISTRÓFICO", medium texture. (mg Kg^{-1}). DEPTHS OF 0-20 and 20- 40 cm. .



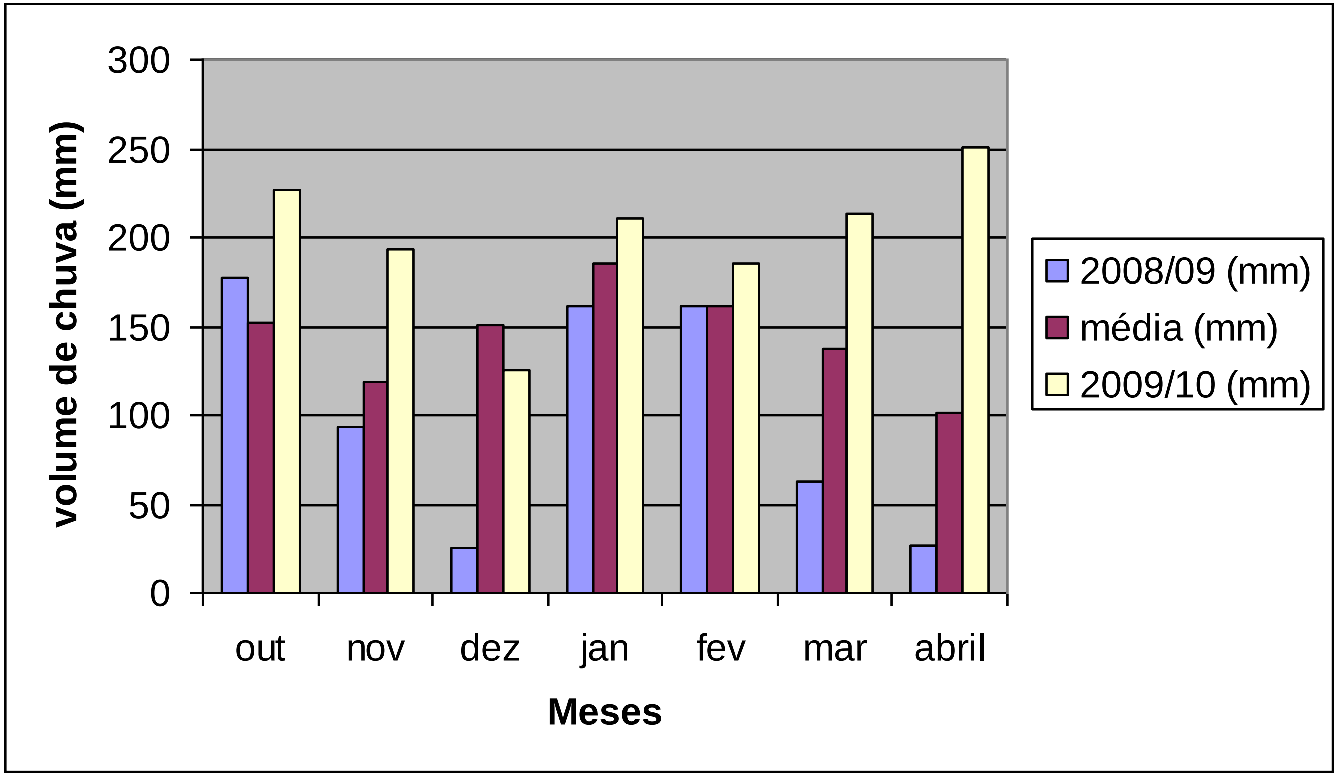
CROP 2009/10
0-20 cm.



CROP 2009/10
20-40 cm.

Source: Silvestrin, 2010

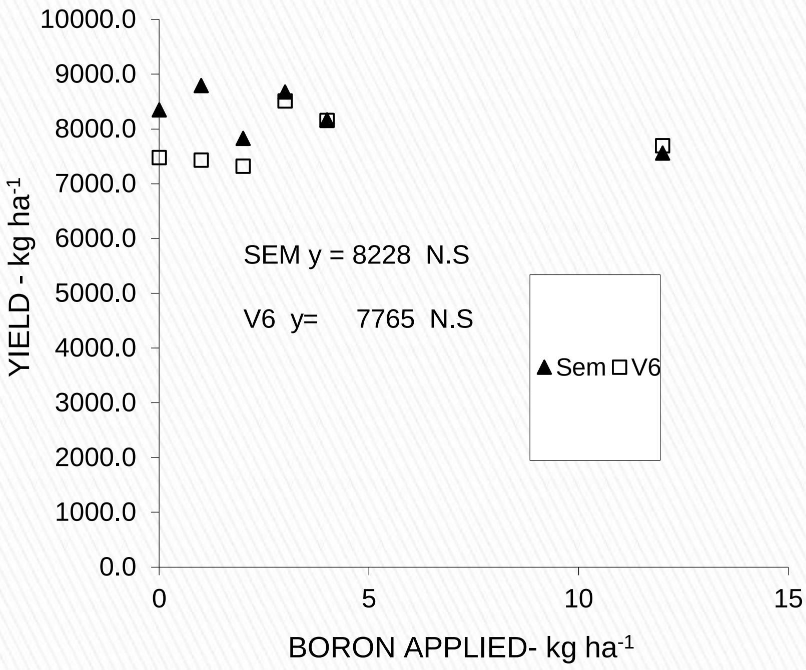
Rainfall between months from October to April of 2008/09 and 2009/10 seasons.

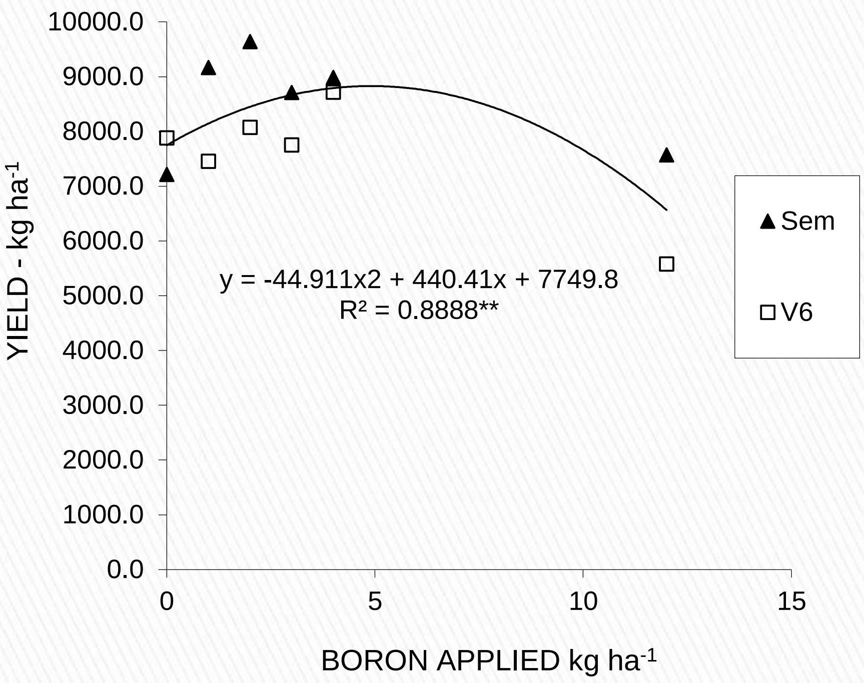


média=average
chuva=rain

SOURCE: Adapted IAPAR, 2010.

YIELD – Kg ha^{-1} 2008/09 and 2009/10 seasons.



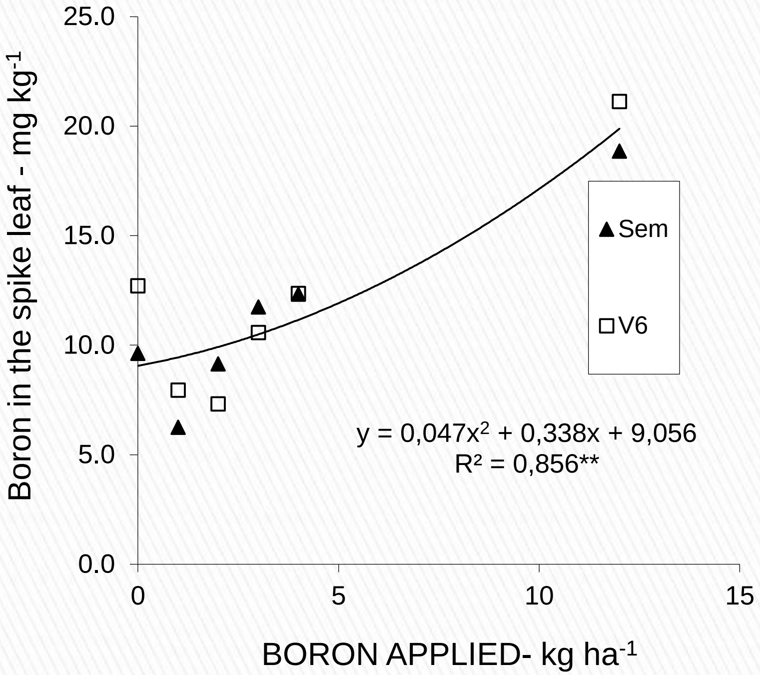


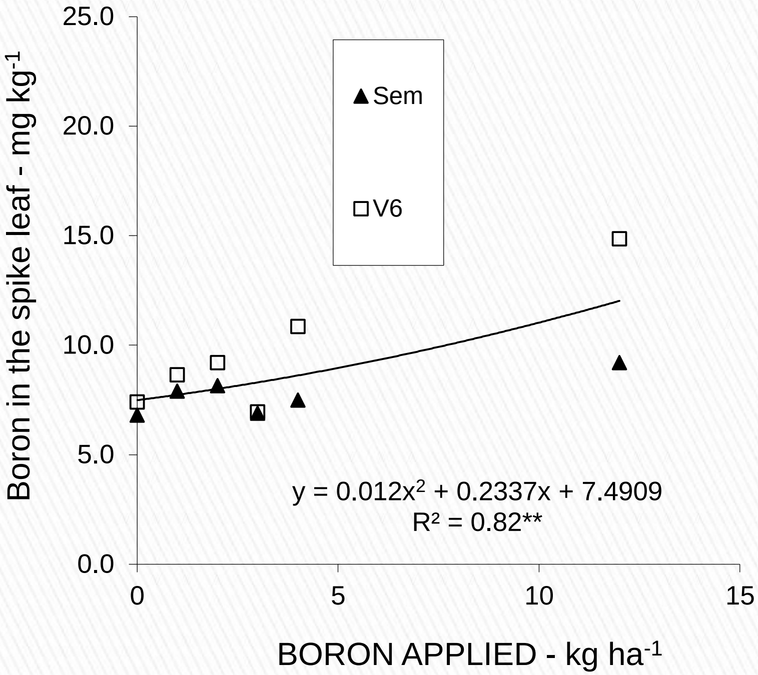
CROP 2008/2009

CROP 2009/10

Silvestrin, 2010

BORON CONCENTRATION OF SPIKE LEAF (mg Kg⁻¹). PLANTING (Sem) AND V6 STADIUM OF MAIZE.





CROP 2008/09.

CROP 2009/10.

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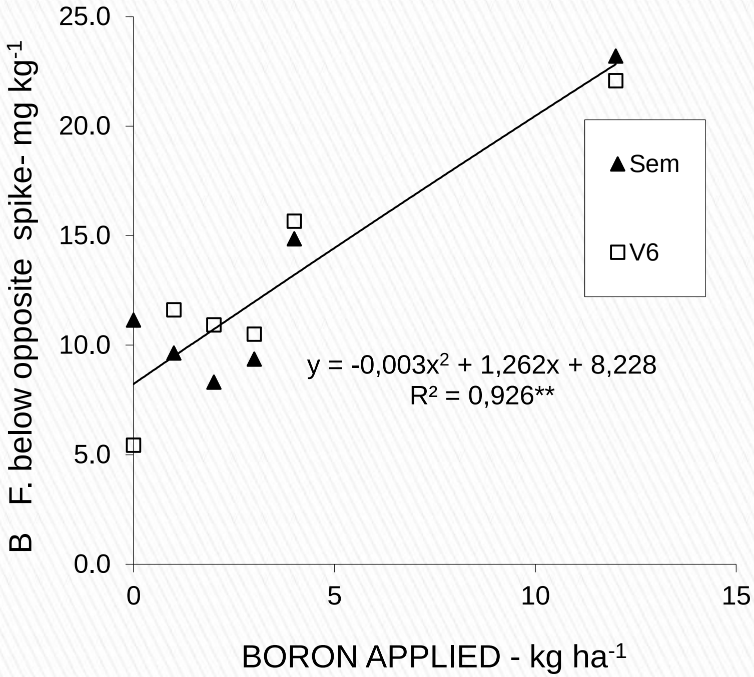
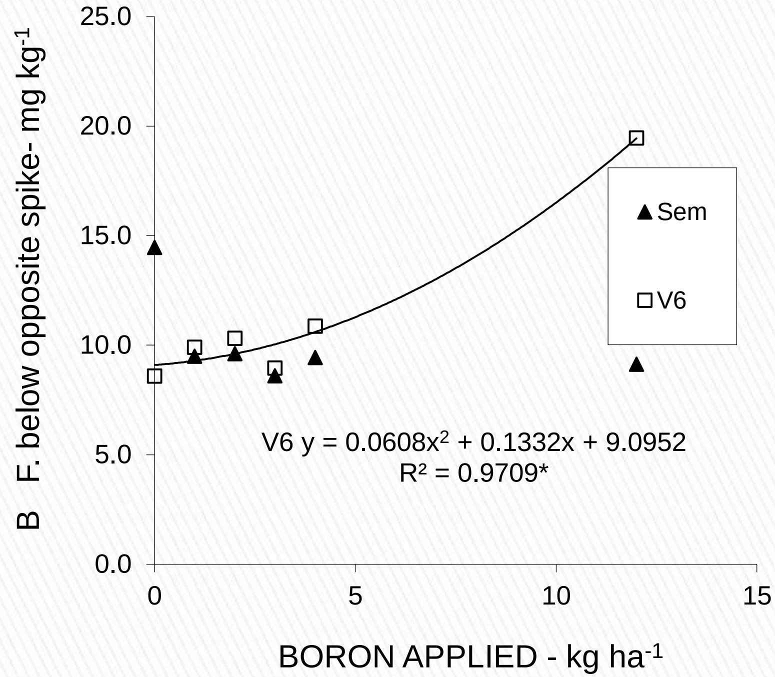
BORON CONCETRATION IN THE FIRST LEAF BELOW AND OPPOSITE THE SPIKE (mg Kg^{-1}). PLANTING (Sem) AND V6 STADIUM OF MAIZE.



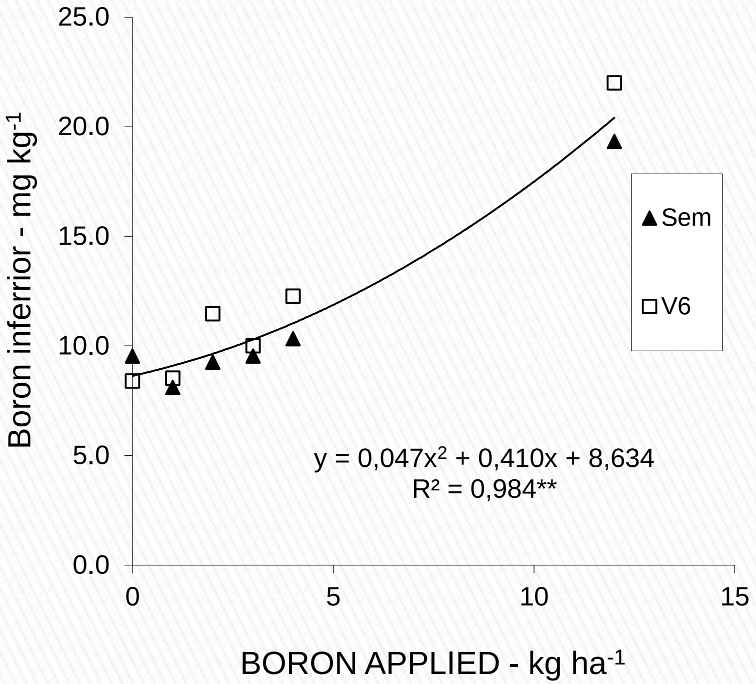


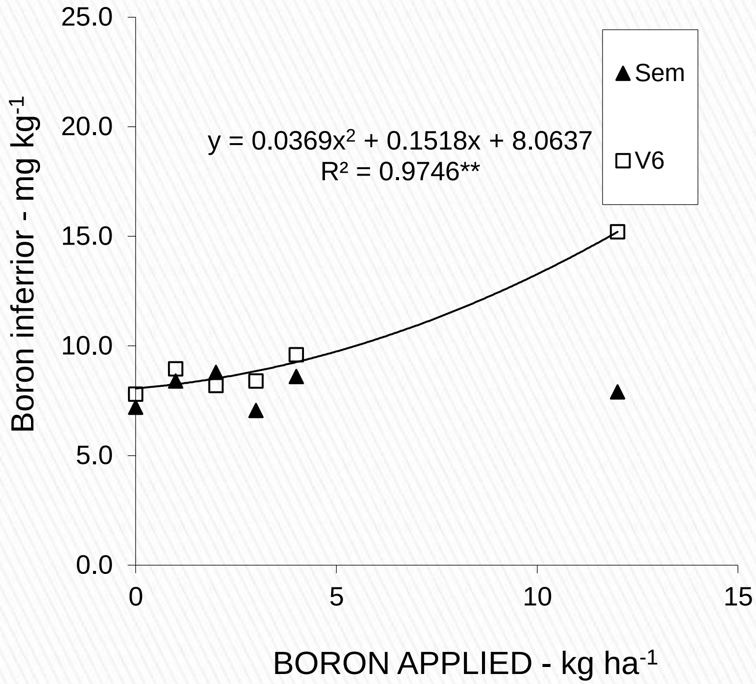
CROP 2008/2009

CROP 2009/10

Silvestrin, 2010

BORON CONCENTRATION IN THE THIRD BOTTOM OF THE FIRST LEAF BELOW AND OPPOSITE THE SPIKE (mg Kg^{-1}). PLANTING (Sem) AND V6 STADIUM OF MAIZE.



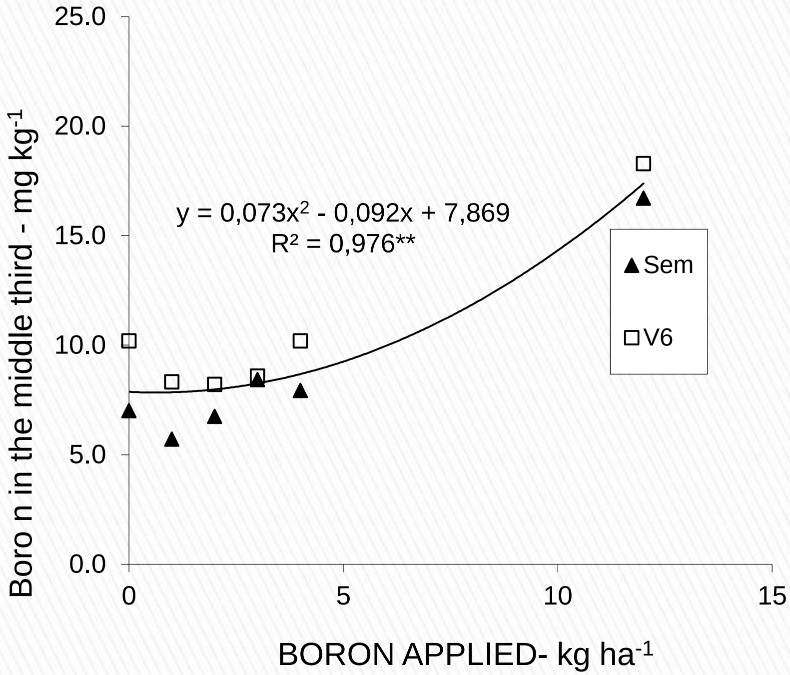


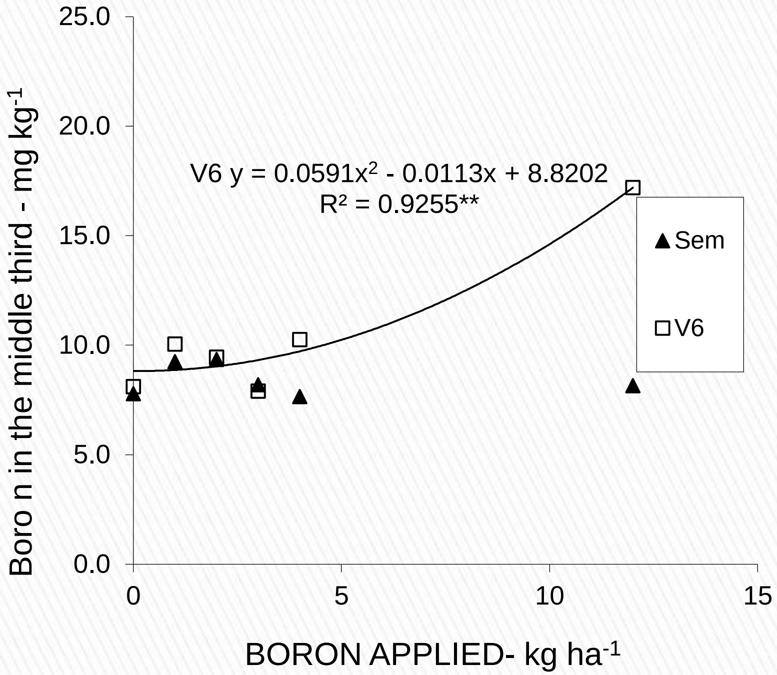
CROP 2008/2009

CROP 2009/10

Silvestrin, 2010

BORON CONCENTRATION IN THE THIRD MIDDLE OF THE FIRST LEAF BELOW AND OPPOSITE THE SPIKE (mg Kg^{-1}). PLANTING (Sem) AND V6 STADIUM OF MAIZE.



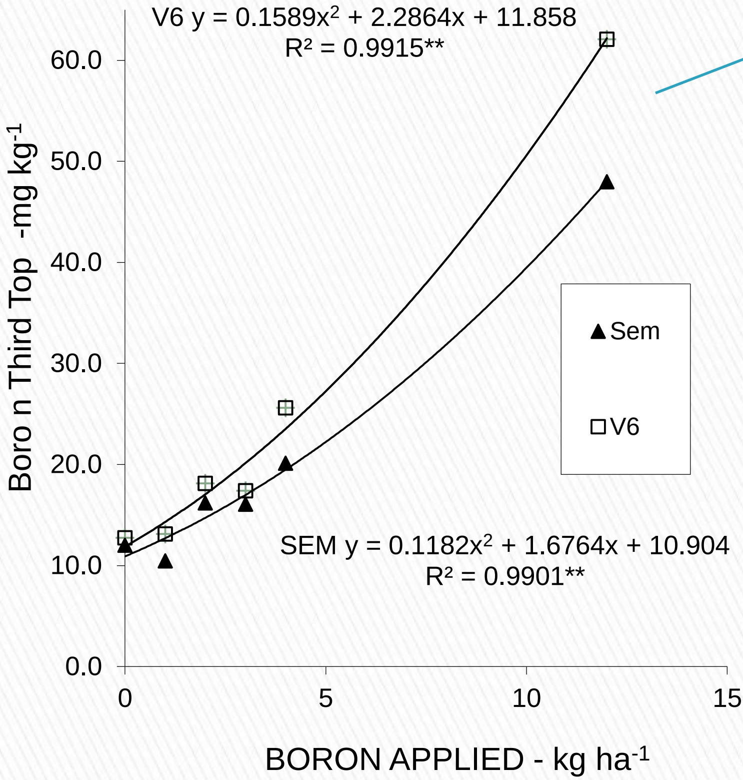


CROP 2008/2009

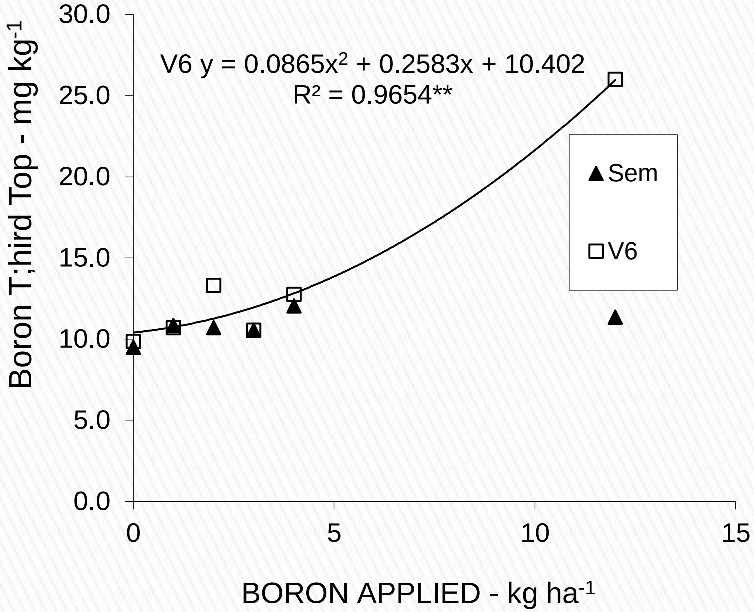
CROP 2009/10

Silvestrin, 2010

BORON CONCENTRATION IN THE THIRD TOP OF THE FIRST LEAF BELOW AND OPPOSITE THE SPIKE (mg Kg^{-1}). PLANTING (Sem) AND V6 STADIUM OF MAIZE.



B accumulation tips and margins

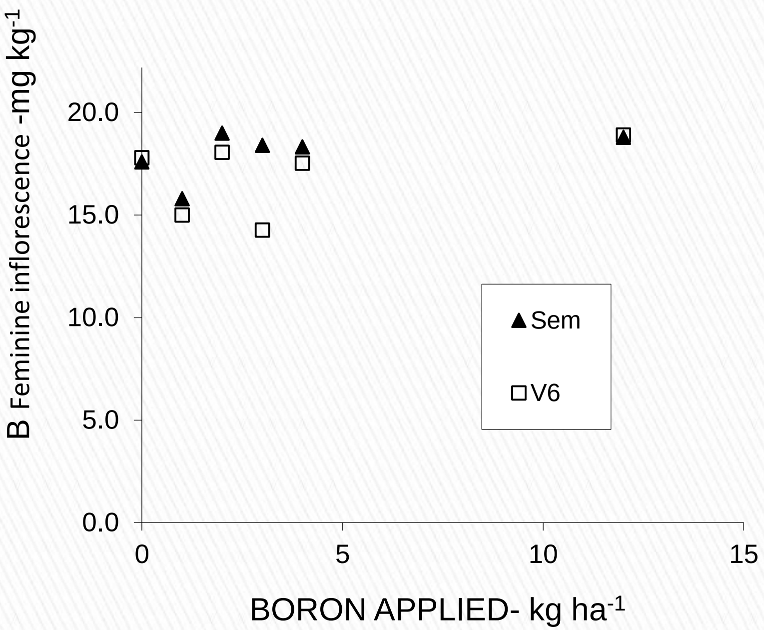


CROP 2008/2009

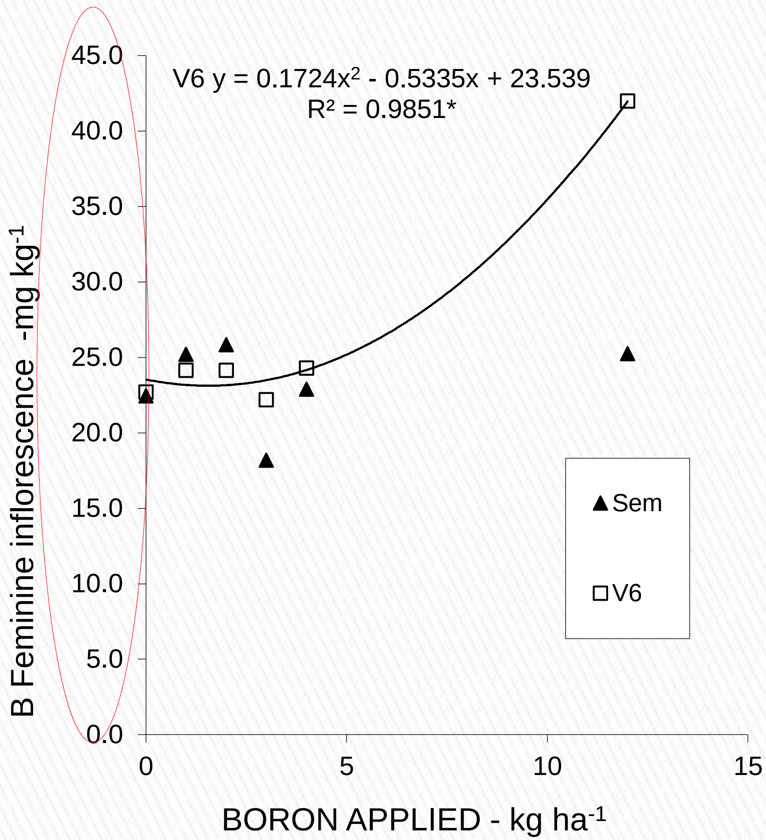
CROP 2009/10

Silvestrin, 2010

BORON CONCENTRATION IN THE FEMININE INFLORESCENCE "HAIR" (mg Kg⁻¹). PLANTING (Sem) AND V6 STADIUM OF MAIZE.



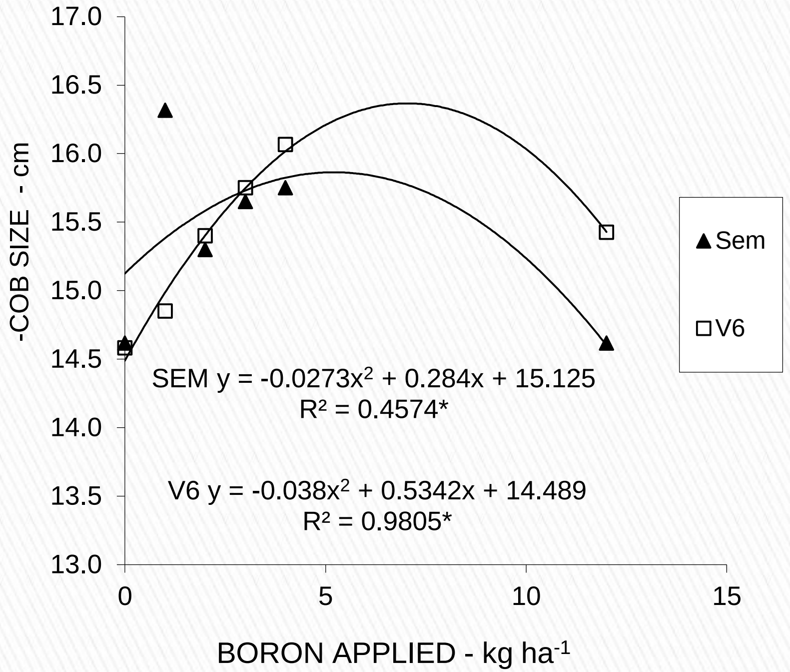
CROP 2008/2009

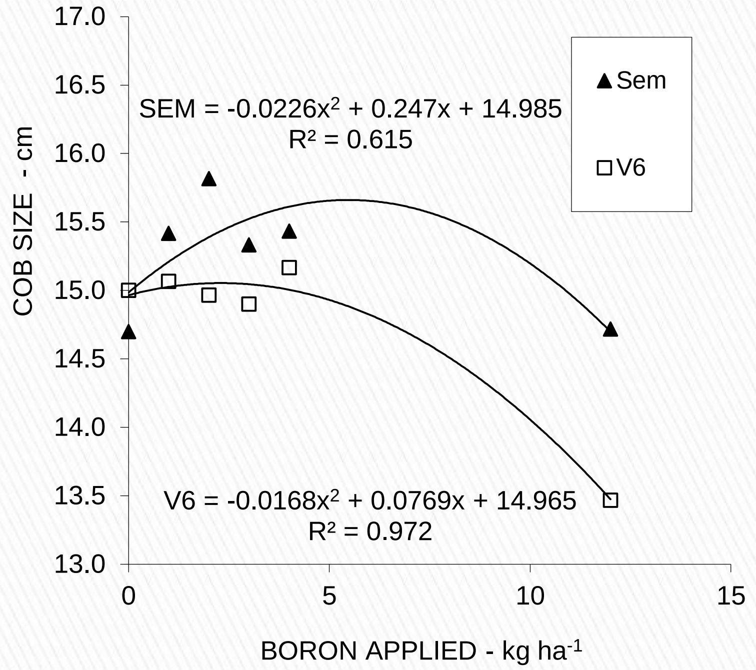


CROP 2009/10

Silvestrin, 2010

COB SIZE – cm





CROP 2008/2009

CROP 2009/10

Silvestrin, 2010

THANK YOU!