# Soil water and nitrate distribution under drip and furrow irrigation regimes for corn

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# Introduction

Nowadays furrow is the irrigation system most commonly used by corn producers in Alt and Baix Empordà (Spain) and in many other production areas around the world.

In recent drought periods water for irrigation has been restricted, therefore farmers are considering to adopt more efficient irrigation systems as drip irrigation.

# Introduction

The region (Alt and Baix Empordà, Spain) is included in the nitrate vulnerable zones in accordance with the water framework directives.

Due to the high density of intensive hog farming in the region it is very common to apply pig slurry as fertilizer.

In the alluvial soils of the region, the irrigation practices and fertilization strategies are the key points in order to minimize ground water pollution with nitrates.

# Introduction

As drip irrigation is not a common practice in extensive crops as corn, it is needed to understand the water and nitrate dynamics in the soil under field conditions in order to prevent nitrate leaching to the aquifers.

# Objectives

1.- To compare soil water distribution in furrow and drip irrigated corn.

2.- To determine soil nitrate distribution and its concentration in the leached solution in a drip irrigated corn field under different fertilization treatments.

3.- To compare grain yield and water use efficiency (WUE) in furrow and drip irrigated corn under different fertilization strategies.

# Procedures

- Field experiment from 2005-2008
- Conducted at Mas Badia Experimental Station (Girona, Spain) in two different fields
- Alluvial soils, Oxyaquic Xerofluvents (SSS, USDA, 2010)
- Sandy-loam (2008) and Silty-loam (2009 and 2010) soil textures

# Procedures in the 2008 experiment
# Furrow irrigation

- 3 replications of 1 irrigation treatment
- Each plot was 130 m long and 4.5 m wide

- Monitored parameters:
  - Irrigation water doses,
  - Advance and recession times
  - Soil water contents at 20, 70 and 120 m from the inflow

- Corn yield was obtained at the start, 1/3, 3/5, 4/5 and at the end of the furrows

# Procedures 2008 experiment

- Distance between plants = 17 cm
- Field slope = 0.0015 m/m

# Procedures 2008 experiment

The furrows were blocked at its end to prevent runoff

# Procedures 2009 experiment

- 3 treatments with 3 replications:
    - Furrow irrigation
    - Drip irrigation, 0.3 m emitter spacing (D30)
    - Drip irrigation, 0.5 m emitter spacing (D50)

- Each plot was 100 m long and 4.5 m wide
- Field slope = 0.005 m/m
- Drip-line spacing: 1.5 m
- Corn rows spaced: 0.75 m
- Emitter flow-rate: 4 L/h
- Monitored parameters: Irrigation water doses for each treatment
- Corn yield was obtained at the start, 1/2, and at the end of the rows.

# Procedures 2010 experiment

- 3 replications of 1 irrigation treatment :
  - Drip irrigation, 0.5 m emitter spacing (D50)

- 20 different fertilization treatments:
  - 2 at pre-planting x 10 during the growing season
  - pre-planting treatments: 0 and 120 kg N/ha from pig slurry
  - Post planting treatments: 0 to 300 kg N/ha with fertigation

# Post planting treatments in 2010 experiment

## Fertigation treatments

(with liquid fertilizer 16% urea, 8% nitrate and 8% ammonium

| Treatment | kg N/ha | | | kg N/ha in total |
|---|---|---|---|---|
| | 13/07/2010 | 21/07/2010 | 20/07/2010 | |
| T1 | 0 | 0 | 0 | 0 |
| T2 | 40 | 0 | 0 | 40 |
| T3 | 40 | 0 | 35 | 75 |
| T4 | 40 | 35 | 0 | 75 |
| T5 | 40 | 35 | 75 | 150 |
| T6 | 75 | 75 | 0 | 150 |
| T7 | 75 | 75 | 75 | 225 |
| T8 | 150 | 75 | 0 | 225 |
| T9 | 150 | 75 | 75 | 300 |
| T10 | 150 | 150 | 0 | 300 |

# Procedures 2010 experiment

From 30/07/2010 until 16/09/2010
Soil samples from T1 and T4 (0 to 75 kg N / ha) were extracted every week at 0, 37.5 and 75 cm from the drip-line, at depths of 15, 45, 75 and 105 cm

# Procedures 2010 experiment

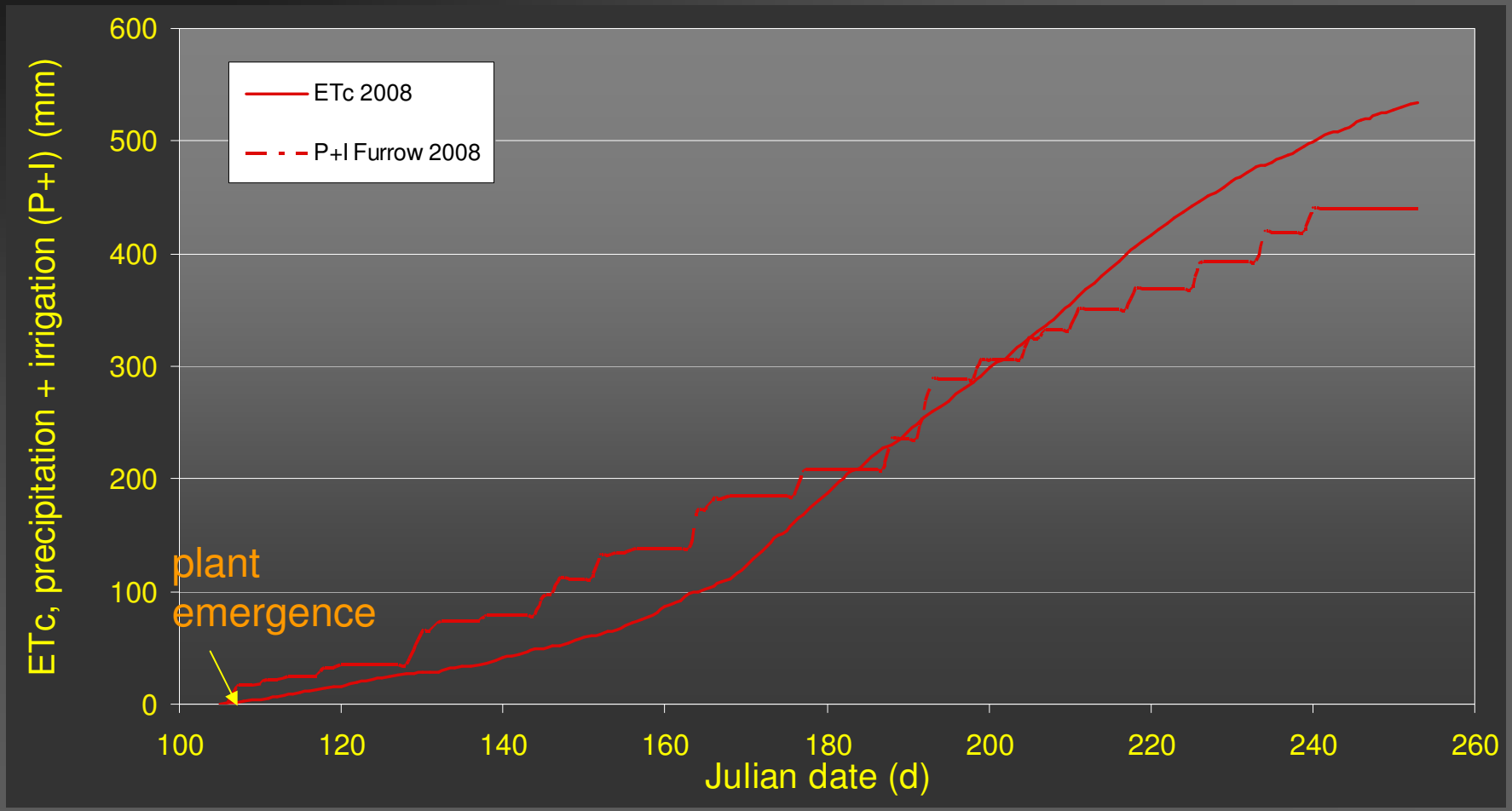
Soil water content was gravimetricaly determined for each position

Moreover soil water content was measured with a TDR in the same position from 0 to 150 cm depth (every 15 cm)

On treatment T4 (75 kg N/ha), with and without preplanting fertilization with pig slurry, nitrates were analysed in the same soil samples

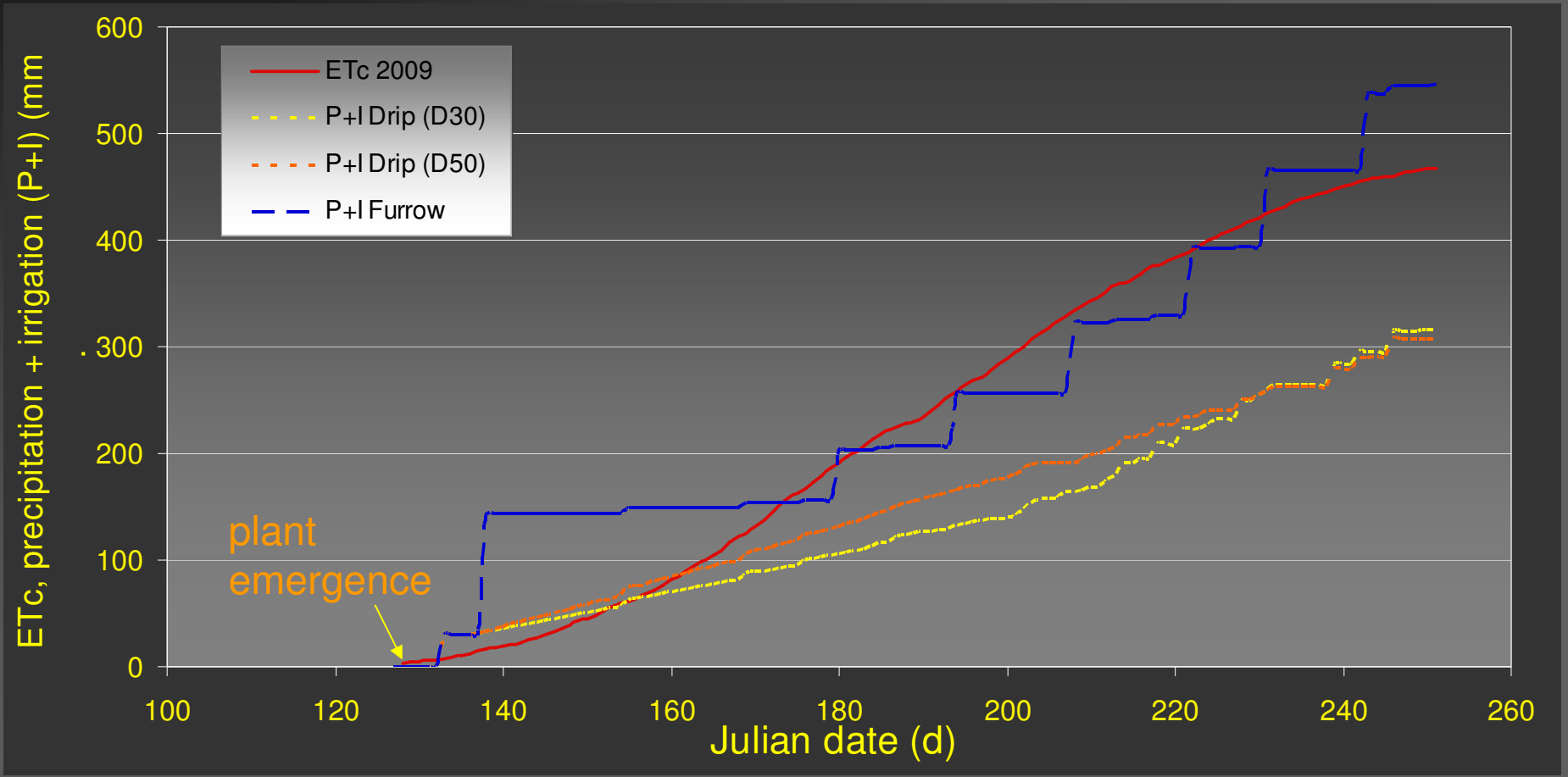
Soil solution was collected every week with suction cups installed at 1.0 m depth in treatments T1 (0 kg N/ha), T4 (75 kg N/ha) and T9 (300 kg N/ha) that received pig slurry

# 2008 irrigation campaign




On 2008, precipitation + irrigation was 94 mm bellow ETc

# 2009 irrigation campaign



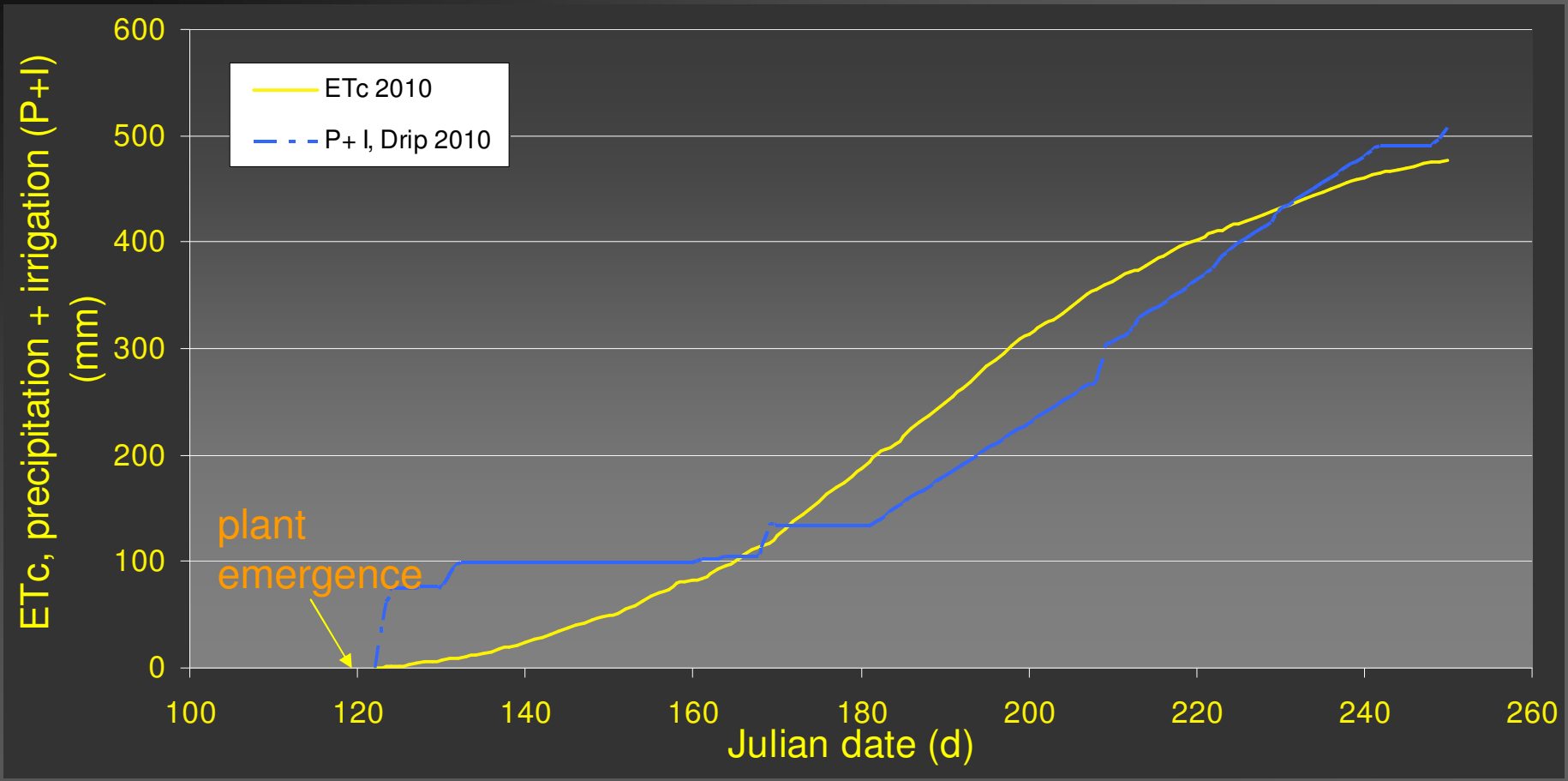

On 2009

In furrow irrigation, precipitation + irrigation was 78 mm greater than ETc

In D30 Drip irrigation, precipitation + irrigation was 151 mm lower that ETc

In D50 Drip irrigation, precipitation + irrigation was 160 mm lower that ETc

# 2010 irrigation campaign




On 2010

Drip irrigation, precipitation + irrigation was 30 mm slightly greater that ETc

# Soil water modeling

Based on Richards equation, soil water distribution was simulated using HYDRUS (Simunek et al., 2006) code

Soil hydraulic properties were take into account using soil van Genuchten-Mualem model

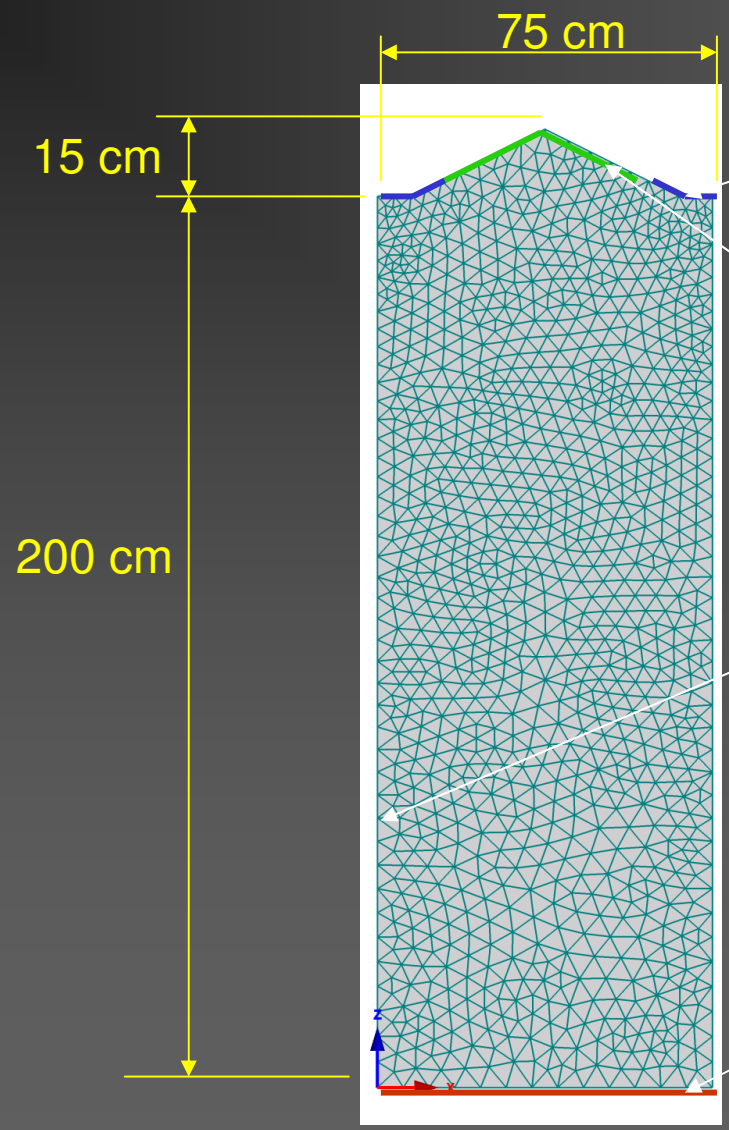
**Simulations:**

- Furrow irrigation: event carried out on August 14, 2008 and redistribution till 8 days later.

- Drip irrigation: period from July 30, 2010 till September, 16/2010

# Soil water modeling

## Furrow irrigation: Flux domain and boundary conditions




Pressure head during the irrigation events

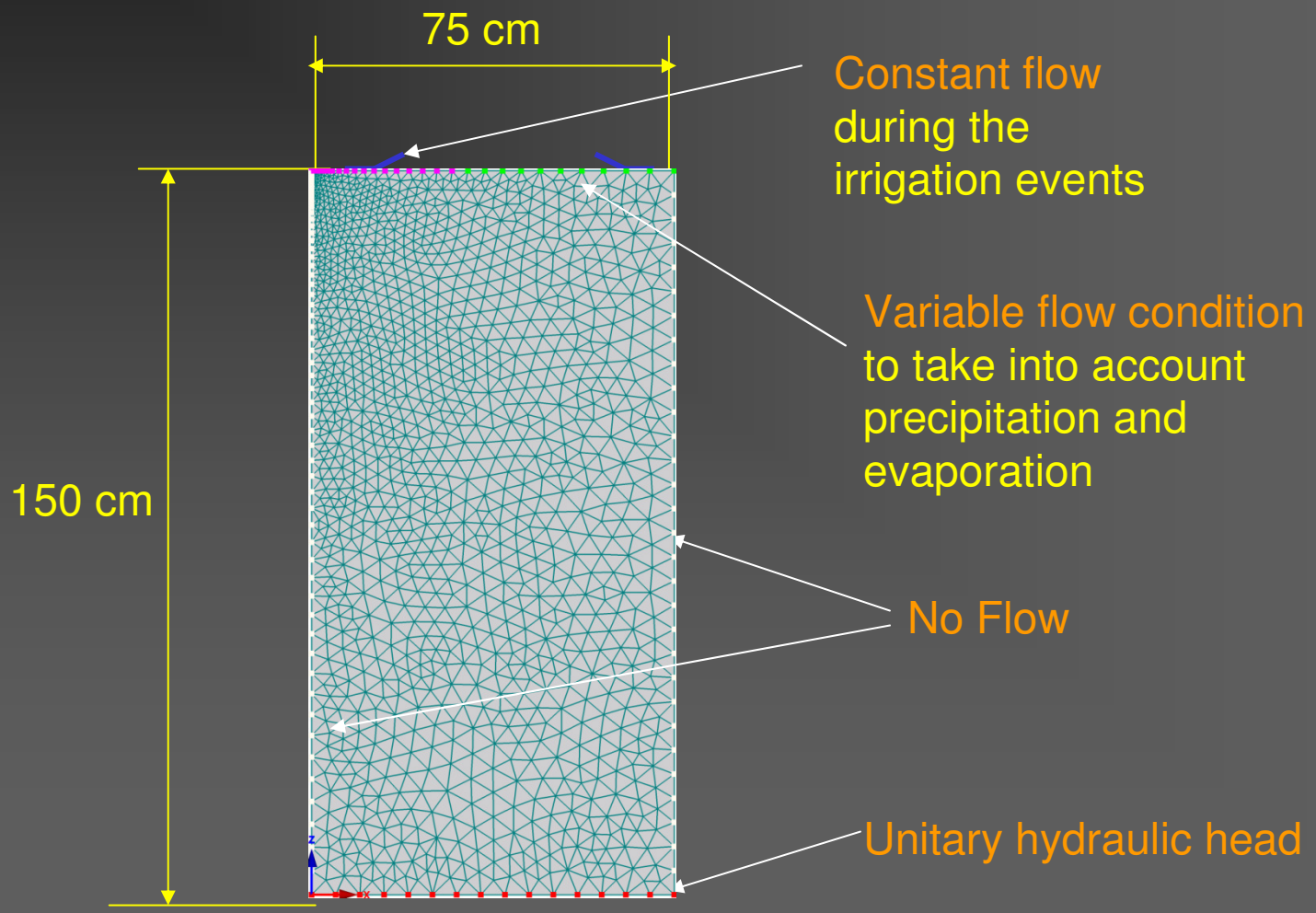
Variable flow condition to take into account precipitation and evaporation

No Flow

Unitary hydraulic head

# Soil water modeling

## Drip irrigation: Flux domain and boundary conditions



# Water Use (WU), Water Use Efficiency (WUE) and Water Deficit (Def)

Water use (WU):

$$WU = Irrigation + Precipitation$$

Water use efficiency (WUE):

$$WUE = \frac{Corn\ Yield}{WU}$$

Water deficit (Def):

$$Def = ETc - WU$$

# Statistical Analyses

GLM procedure of the SAS statistical package was used

In Treatment T4 (75 kg N/ha), the model analyzed, **soil water distribution**, **soil nitrate content**
The model included as fixed effects:

- Application or not of organic fertilizer at pre-planting,
- Depth
- Horizontal distance to the emitter
- Date
- and their interactions.

LSD's pairwise comparison was used to identify means that were different at $p<0.05$

# Statistical Analyses

GLM procedure of the SAS statistical package was used

In treatments T1 (0 kg N/ha), T4 (75 kg N/ha) and T9 (300 kg N/ha) that received pig slurry the model analyzed **nitrate concentration in the leached** in 2010

The model included as fixed effects:

- Amount of applied N during the growing season
- Depth
- Horizontal distance to the emitter
- Date
- and their interactions.

LSD's pairwise comparison was used to identify means that were different at $p<0.05$

# Statistical Analyses

GLM procedure of the SAS statistical package was used

The model analyzed **drained water in 2010**

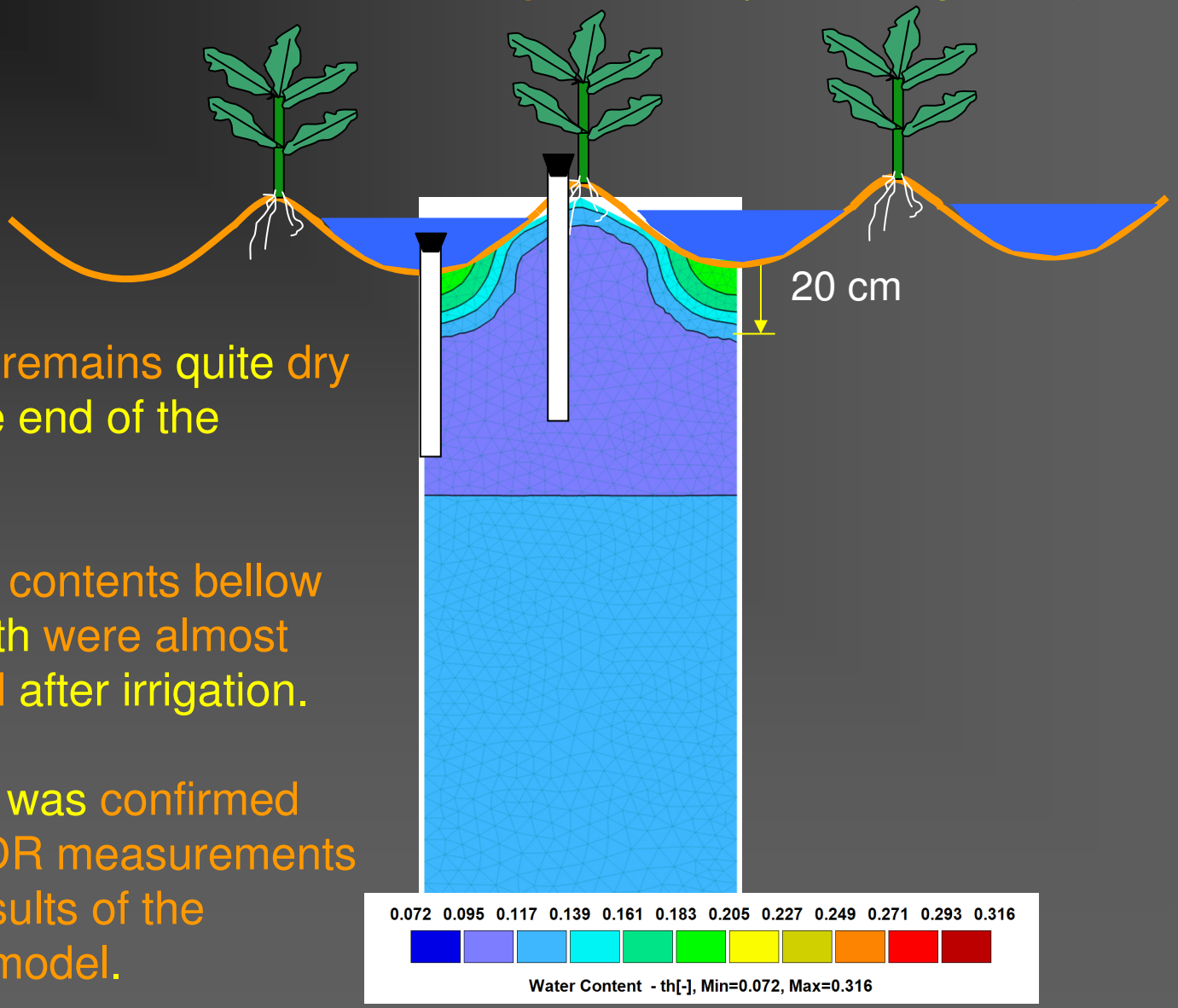
The model included as fixed effects:

- Position:
  - emitter
  - plant
  - mid distance between two drip-lines (no emitter)
- Date

LSD's pair-wise comparison was used to identify means that were different at $p<0.05$

# RESULTS AND DISCUSSION

Soil water distribution under furrow irrigation 1 day after irrigation (2008)




- The ridge remains quite dry even at the end of the irrigation
- Soil water contents bellow 20 cm depth were almost unchanged after irrigation.
- This point was confirmed with the TDR measurements and the results of the HYDRUS model.

# RESULTS AND DISCUSSION

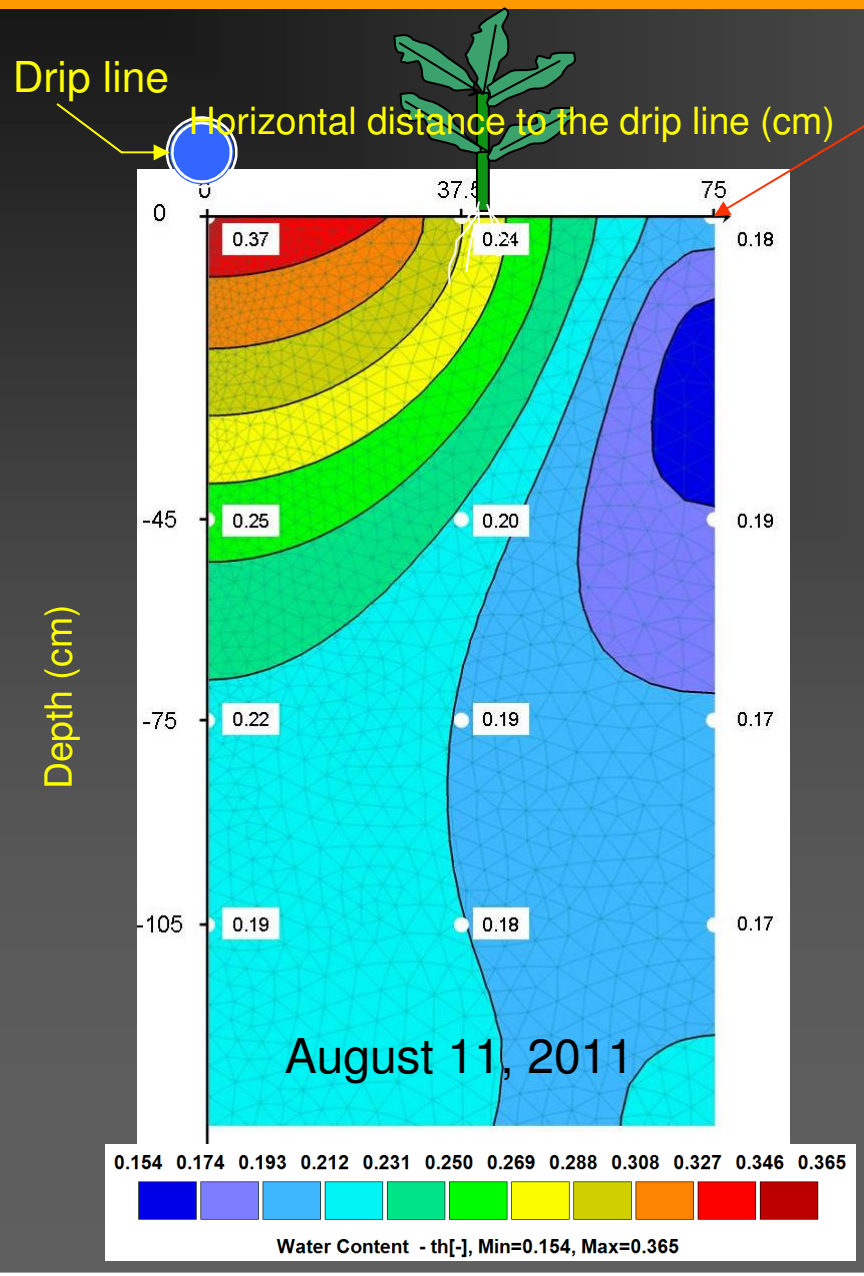
## SOIL WATER CONTENTS UNDER DRIP IRRIGATION 2010 EXPERIMENT

The soil water content throughout the irrigation campaign depended significantly ($p < 0.05$) on the soil depth and the horizontal distance from the drip-line, but did not depend on the application of the manure

The soil water content decreased when the horizontal distance to the lateral and soil depth increased

At 1.05 m depth, soil water contents remains practically unchanged independently of the distance to the drip line

# Soil water distribution simulated with **HYDRUS** and **measured from soil samples**




The drier region was in the **mid distance between two drip lines**

The model accurately predicted the water content

The wetting front reached the region were the plant grown (37.5 cm form the drip line).

Similar wetting patterns were observed along the irrigation season

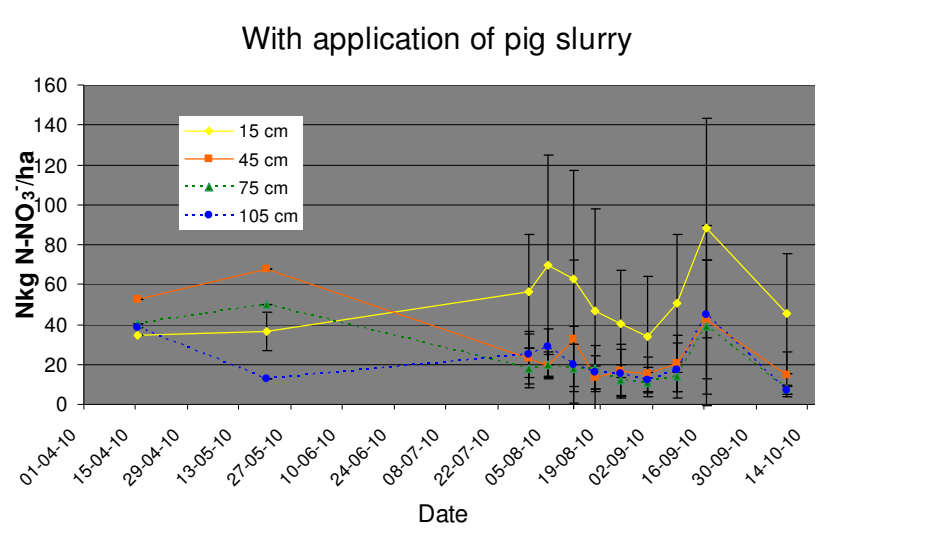
**Good agreement** between soil water contents determined gravimetrically and simulated with HYDRUS

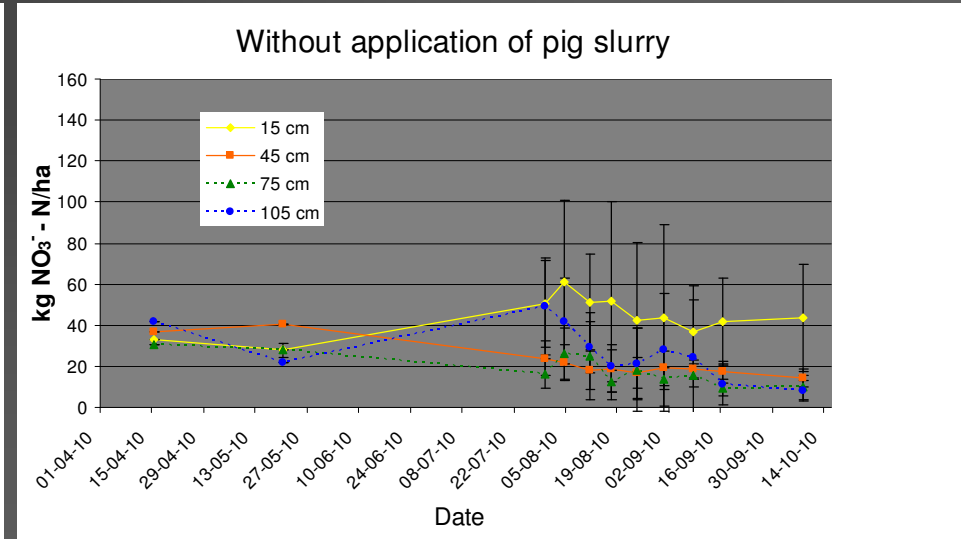
# RESULTS AND DISCUSSION

## Soil Nitrate Distribution under drip irrigation 2010 experiment

- **Soil Depth**

During most of the period **soil nitrate content at 15 cm depth was significantly greater** ($p>0.05$) than other soil depths



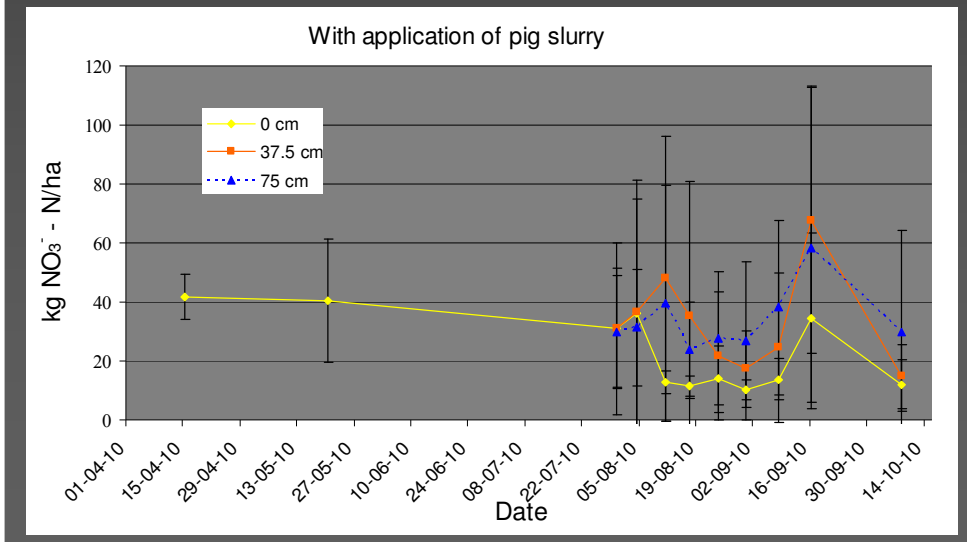

Except for one particular date (September 16, 2010) **there were no significant differences** ($p>0.05$) among the treatments that received or did not pig slurry.

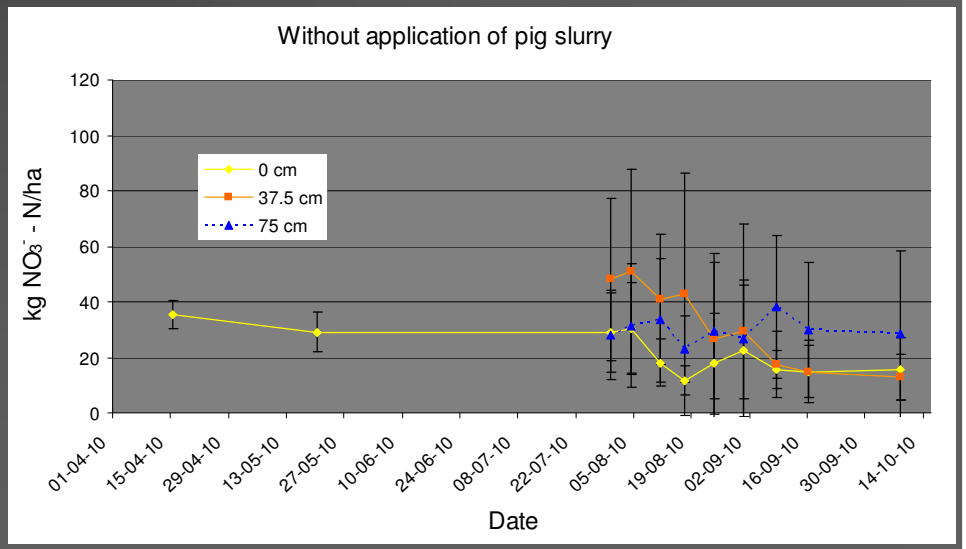
# RESULTS AND DISCUSSION

## Nitrate Distribution at different distances from the drip-line

During most of the period soil nitrate content at **37.5** and **75 cm** from the drip-line **were greater** ($p>0.05$)

This suggest that **nitrate move away from the drip** line up to the periphery of the wetted region



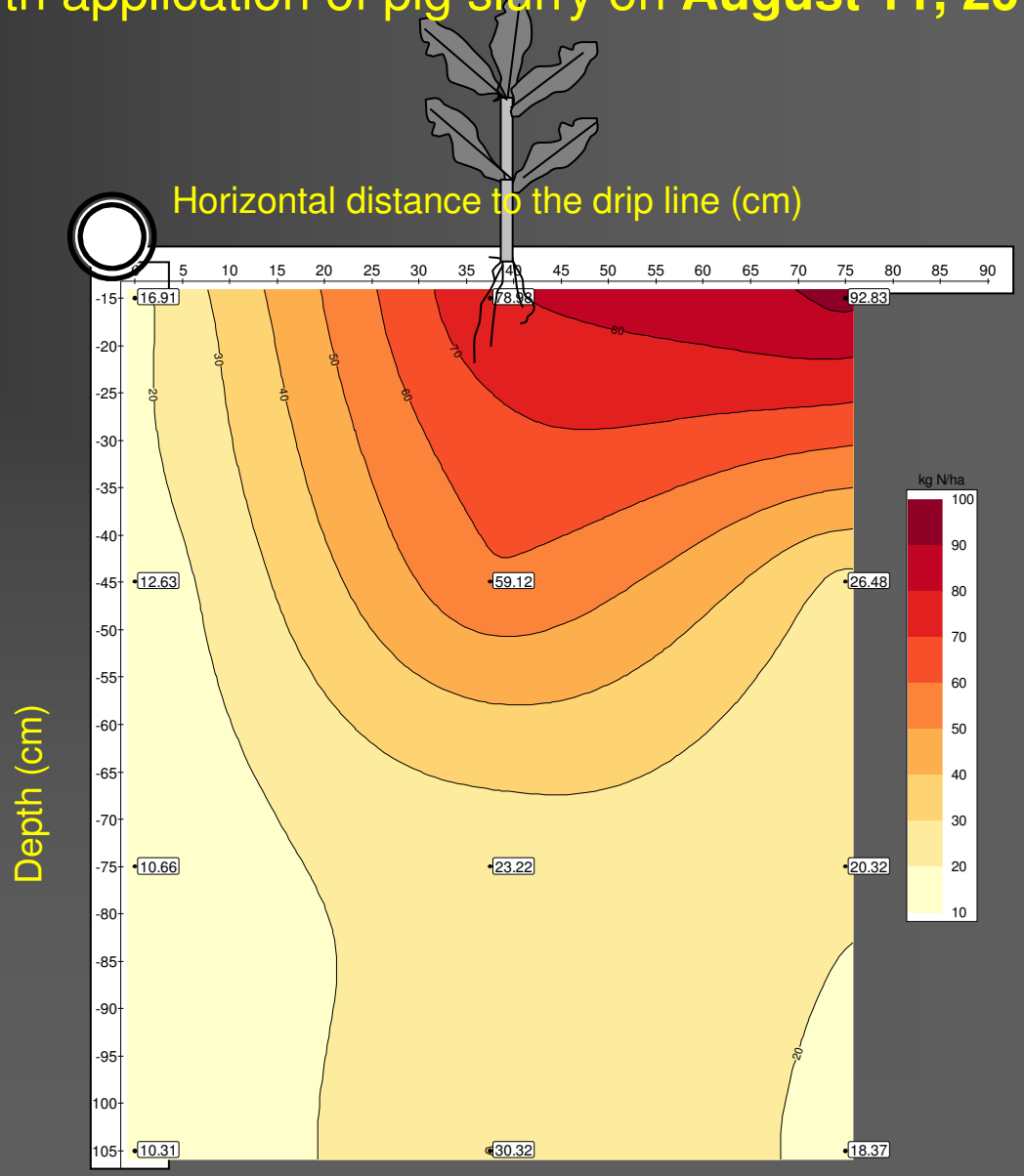



# Nitrate Distribution from the drip line

Treatment T4 (75 kg N/ha), with application of pig slurry on **August 11, 2010**

Nitrate content was **greater at the soil surface** than at deeper soil depths

**Nitrate content was greater and at 37.5 and 75 cm** from the drip line than at the position of the drip line



# Nitrate concentration in the leached solution

On treatment T9 (300 kg N/ha) there were significant differences among the different dates, being **higher at the end of the crop cycle**

On Treatment T1 (0 kg N/ha) and T4 (75 kg N/ha) there were no significant differences among the dates

The average nitrate concentration (ppm) during all the period in the leached solution for the different treatments was:

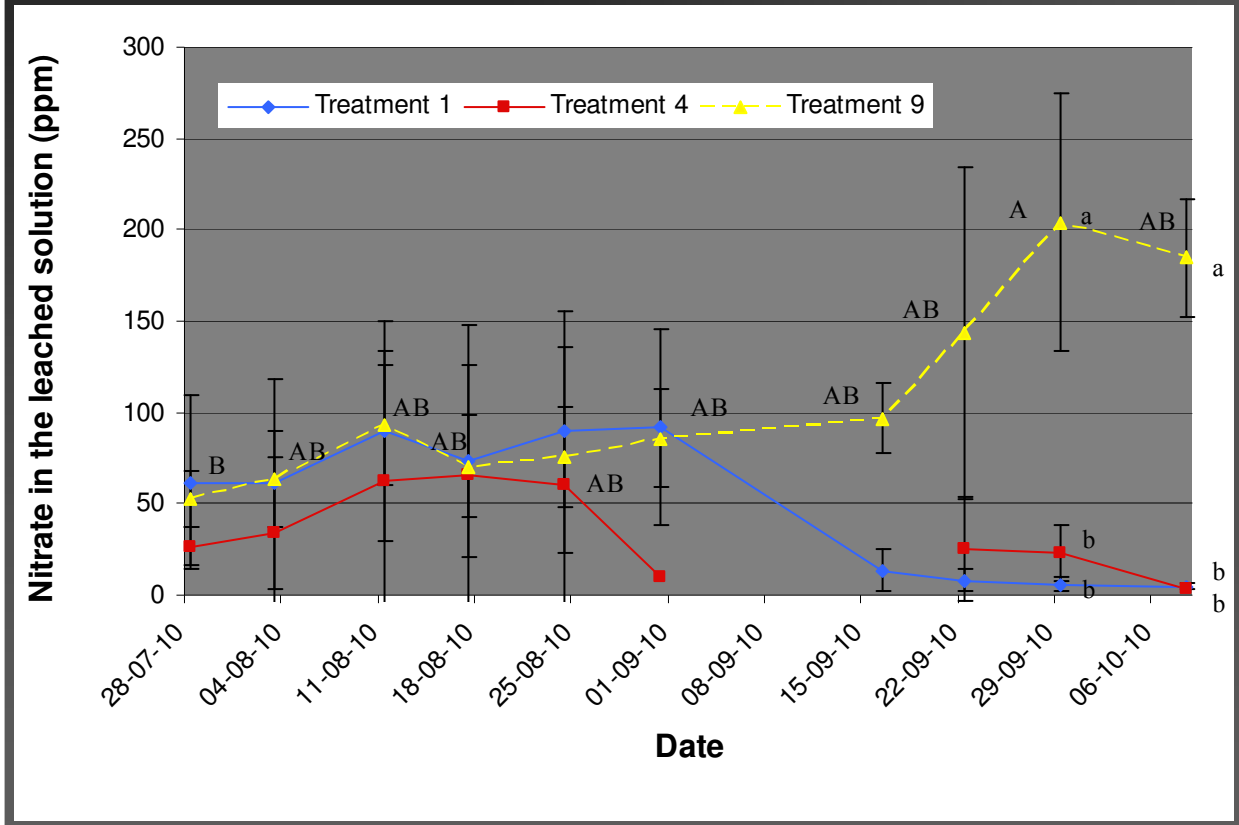
| T-1<br>(0 kg N/ha) | T-4<br>(75 kg N/ha) | T-9<br>(300 kg N/ha) |
|---|---|---|
| $42.6^{B}$ | $35.0^{B}$ | $104.9^{A}$ |

Different upper-case letters means significant differences among treatments at $p<0.05$

# Nitrate concentration in the leached solution

The greater differences were on September 29, just after to harvest the corn.

There were no significant differences between T1 (0 kg N/ha) and T4 (75 kg N/ha)

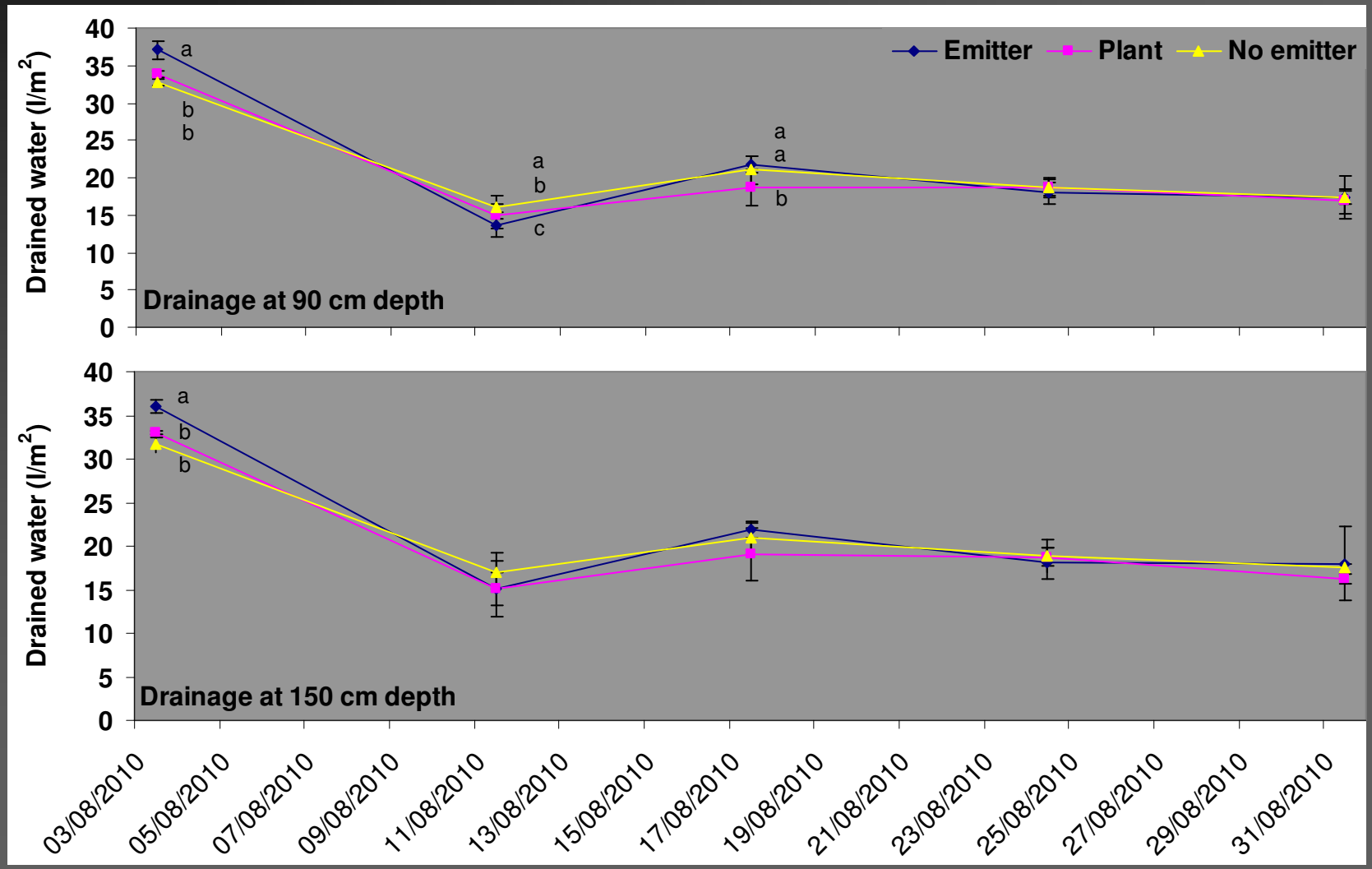



From September 29, nitrate concentration tends to reduce in all the treatments due to the irrigation events.

Different upper-case letters means significant differences ($p<0.05$) among different dates.

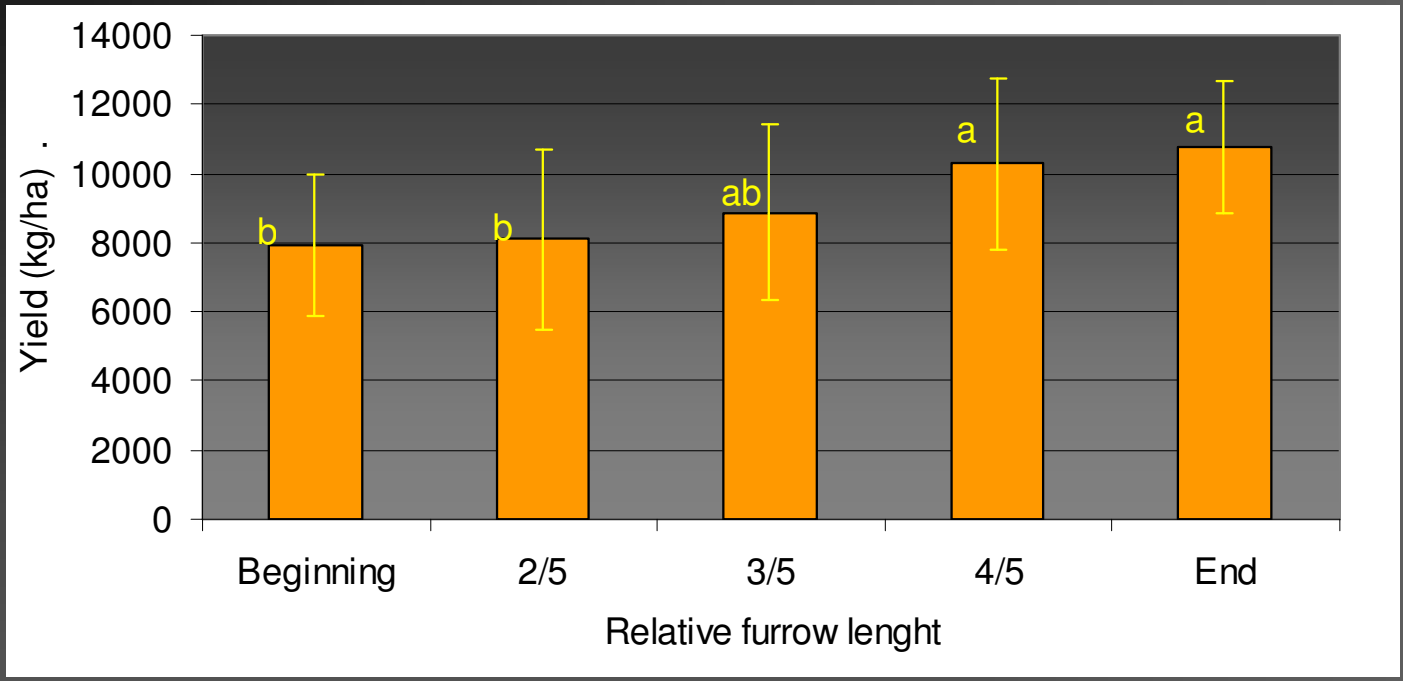
For each date, different lower-case letters means significant differences ($p<0.05$) among treatments

# Weekly drained water (l/m²) at 90 and 150 cm depth for the different positions (emitter, plant and no emitter) calculated from the TDR readings




By each date, different letters means significant differences among positions at $p<0.05$

# Corn Yield along the furrow (blocked end furrow) – 2008 experiment




Significant ($p<0.05$) greater corn yield at the end of the furrow due to the greater infiltrated water depth in those positions

This shows the effect of the low uniformity in the water distribution, especially when the irrigation water dose was bellow the irrigation needs

# Corn Yield – 2009 experiment

| | Drip irrigation D30 | Drip irrigation D50 | Furrow irrigation |
|---|---|---|---|
| Water Use (Irrig + Precip.) (mm) | 316.0 | 307.9 | 545.6 |
| **Yield (Mg/ha)** | **13.70** | **12.92** | **13.99** |
| WUE (kg/m3) | **4.335** | **4.196** | **2.564** |

The drip irrigated treatments received a lower water dose but the yield was not affected, consequently: **WUE was noticeable higher when using drip irrigation**

## Corn Yield – 2010 experiment

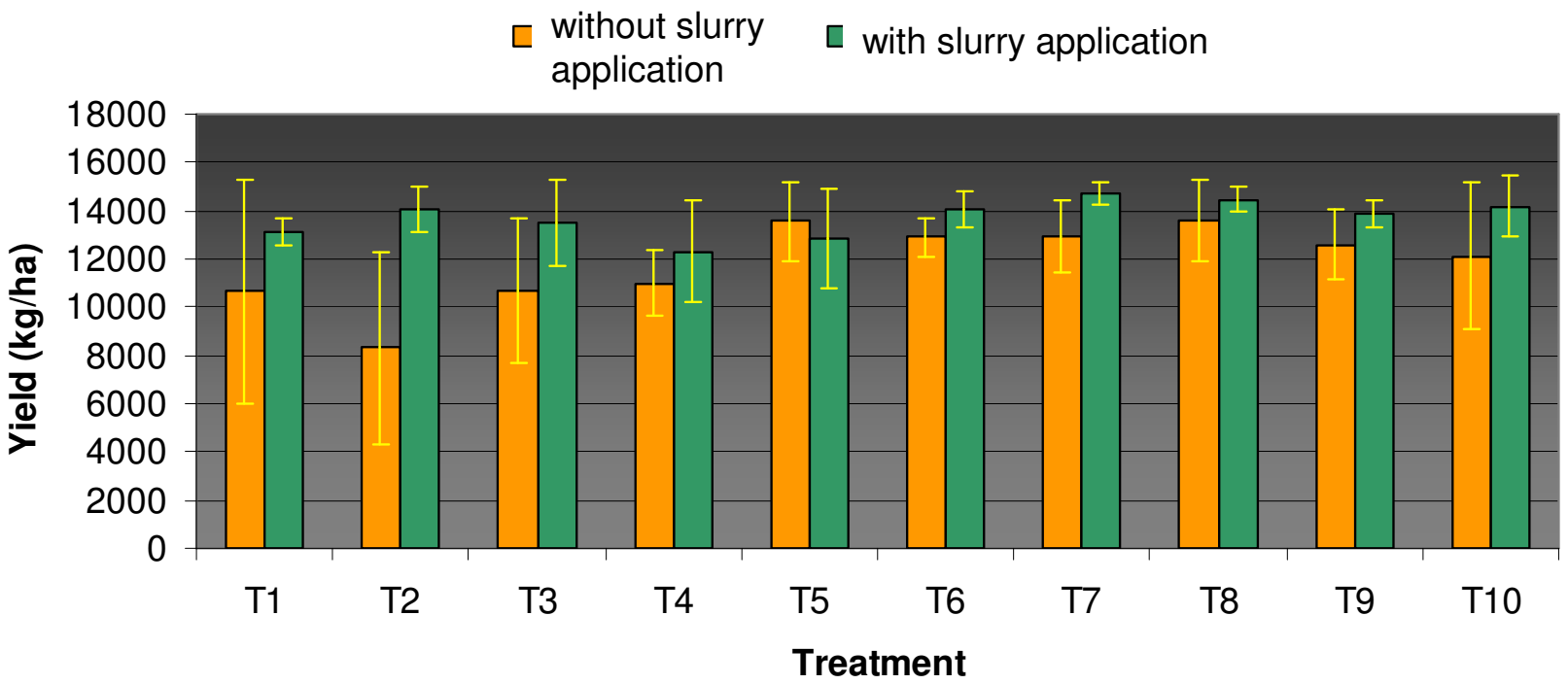
There were significant differences on the mean corn yield among the treatments that received pig slurry as pre planting fertilizer and the treatments that did not received it

Mean corn yield (Mg/ha)

| | |
|---|---|
| With application of pig slurry | 13.7 [a] |
| Without application of pig slurry | 11.8 [b] |

**CORN YIELD was significantly higher for the treatments that received pig slurry**

# Corn Yield – 2010 experiment




There were no significant differences on corn yield among the different fertigation treatments receiving from 0 to 300 kg N / ha

The treatments that did not received slurry and received a lower application dose of N (0 to 75 kg N /ha) during the growing period were the ones that produced less (T1 to T4)

# CONCLUSIONS

- Furrow irrigation on a sandy-loam soil did not allow to moisture the ridge, were the corn plants grew, which reduced potential corn yield.
- Drip irrigation on a daily basis allows to maintain a soil wetted region large enough for the corn development.
- Although differing values of WUE were observed among years, comparisons in the same year show that WUE was higher for drip irrigation.
- The soil nitrate distribution throughout the irrigation campaign indicates that nitrate moves with the water from the emitters, accumulating at the periphery of the soil wetted pattern.

# CONCLUSIONS

- In drip irrigation the application of pig slurry at pre-planting maintained corn yield with minimal or even none application of nitrogenous fertilizer during the growing season.
- The application of a high amount of nitrogen fertilizer during the growing season (300 kg N / ha) increased the concentration of nitrate in the leachate solution without increasing corn yield.