Media and Plants to Optimise Phosphorus Removal and Carbon Sequestration in Sub-Surface Flow Wetlands

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Background to Research Questions

- Vegetation is an important component of wetland systems for water quality improvement
- Benefits of plants in nutrient uptake are often under-rated because at high HLR the % removal is relatively small especially for phosphorus
- Media can enhance phosphorus adsorption in subsurface flow wetlands for wastewater and in bioretention systems for stormwater
- Carbon sequestration is an increasingly important attribute of wetlands

Subsurface-Flow Wetlands and Bioretention Systems

Horizontal Subsurface Flow-Sewage Treatment Wetlands

Vertical Flow Bioretention Systems- Stormwater Treatment

Background

- Plant species can vary in their ability for luxury uptake of phosphorus and storage of carbon
- Phosphorous sorption capacity of media determines long term P removal & retention
- After the sorption capacity is reached, P is no longer removed & desorption may occur, resulting in export of P.
- Media used in subsurface flow CW's is typically gravel and/or sand (good hydraulic conductivity)
- Generally gravel and sand have poor adsorption capacity for phosphorus

Aims of Research Project (commenced 2003)

1. To investigate the effect of different media (including media amendments) on phosphorus retention.
2. To investigate the effect of media saturation on phosphorus retention.
3. To investigate the effect of vegetation on P retention.
4. To quantify phosphorus uptake and carbon sequestration in different plant species.

Bioretention Mesocosm Experiments

Griffith University-Experimental Setup 240L Mesocosms

- Half the mesocosms are vegetated. Half are barren.
- Recycled effluent loaded weekly 112L. Mean inflow 4.8mgTP, 3.94mg PO4; (5mgTN, 2.72mg NOx, 0.74mg NH4)
- Inflow distributed by a manifold system and regulated drippers.
- Outflows collected in 3m long chambers of 250mm pipes (135 L) .

Thanks to Vinidex for the collection chambers!

Experiment 1–June 2003- March 2007

Acknowledgements- Courtney Henderson, Bill Lucas, Daya Gautum

30 mesocosms : 3 different media

gravel;

sand (4% silt/clay);

loam (8% silt/clay)

Vegetated and Non-vegetated (barren) treatments

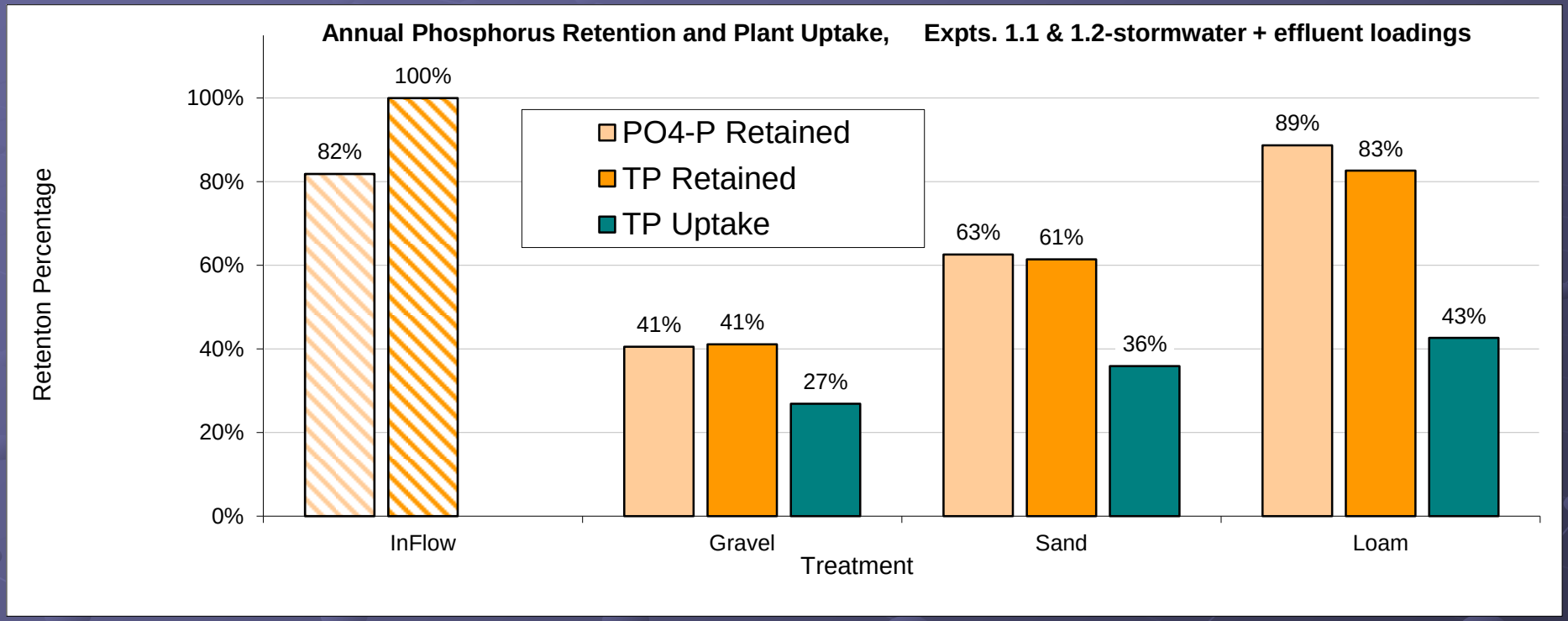
Stormwater(low P) loading (2003-2005) plant establishment

Effluent loading commenced after 3 years(2006-2007).

Experiment 1 Plants

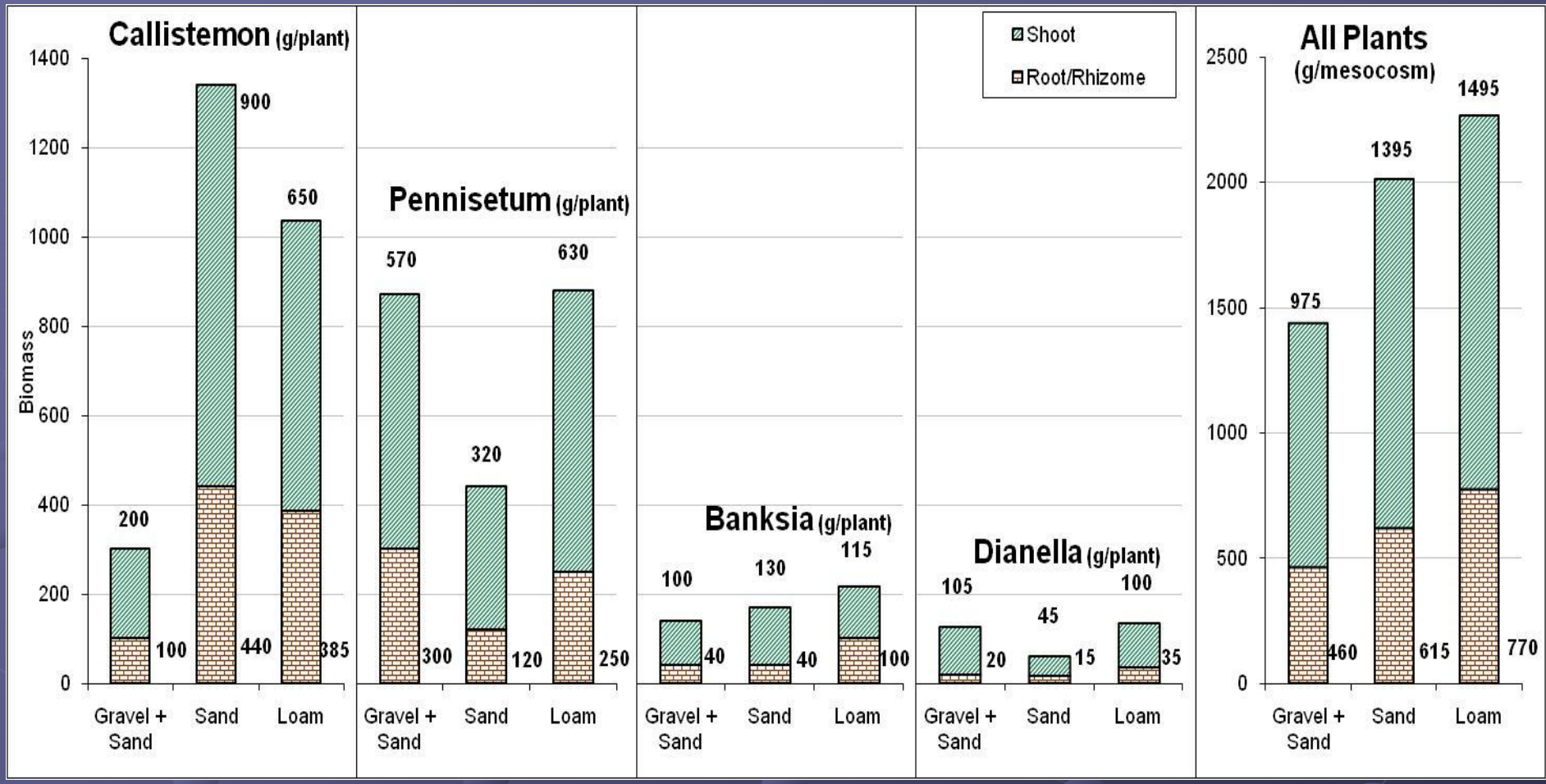
Grass*: Pennisetum alopecuroides*
Lily: *Dianella brevipedunculata*
Shrubs *: Callistemon pachyphyllus; Banksia integrifolia*
Succulent creeper :*Carpobrotus glaucesens*

Expt 1 % P retention & TP plant uptake after load 105gP/m2 - gravel, sand, loam



- Phosphorus Retention highest in loam (89% PO4),then sand
- P retention exceeded plant uptake
- Chemical adsorption and microbial uptake important mechanisms
- Plant uptake highest in loam (43%) (better growth)

Expt 1 Shoot/Root Biomass after 4.5 years



- Callistemon and Pennisetum had the highest biomass
- Total plant biomass was highest in the loam media

Bioretention Mesocosm Experiments - Experiment 2 (2007-2012)

27 mesocosms 240 L wheelie bins : -9 treatments (3 replicates)

SAND PLUS Media Amendments:

- **Krasnozem soils**: Red clay soils derived from weathering of ancient basalt
- **Red Mud**: By-product of refining bauxite into aluminium. Mostly clay/silt with fractions of Al & Fe oxides
- **Water Treatment Residuals** : Al-WTR 'sludge' residues from water treatment processes dominated by aluminium hydroxides, plus clay & organic matter.

Experiment 2–January 2007- Jan 2012

Acknowledgements: Bill Lucas, Wendy Tang

- Media treatments formulated for phosphorus retention:

Sand (60-80%)

Sand plus Krasnozem (K)- 3 treatments: (20%, 30%,40%

Sand plus **Red Mud** (RM)- 2 treatments: 6% and 10%

Sand plus Water Treatment Residuals (WTR)- 30%

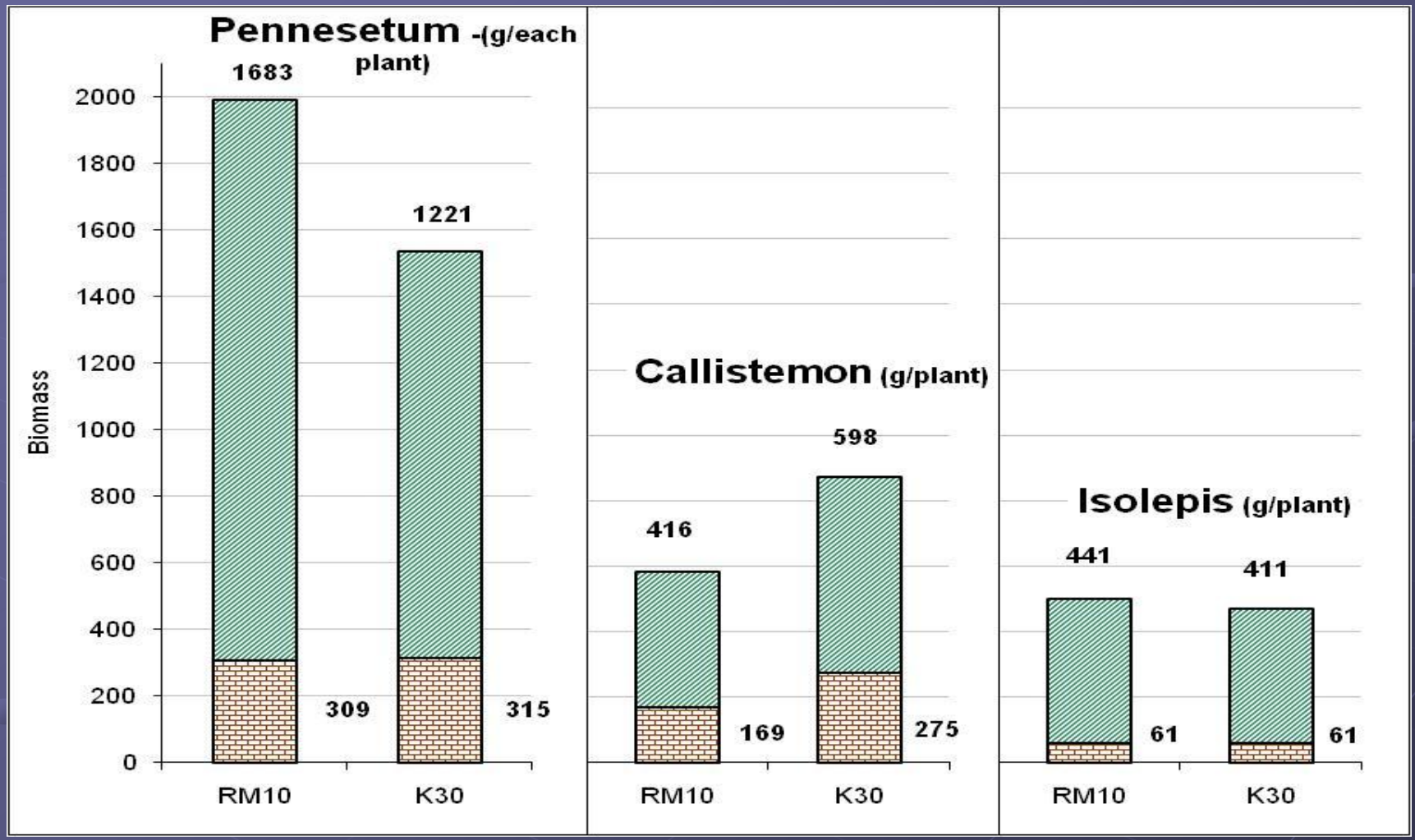
Sand plus Water Treatment Residuals 10% + Krasnozem 20% (WTR-K)

All media plus 12% by volume coir peat

Experiment 2 Plants

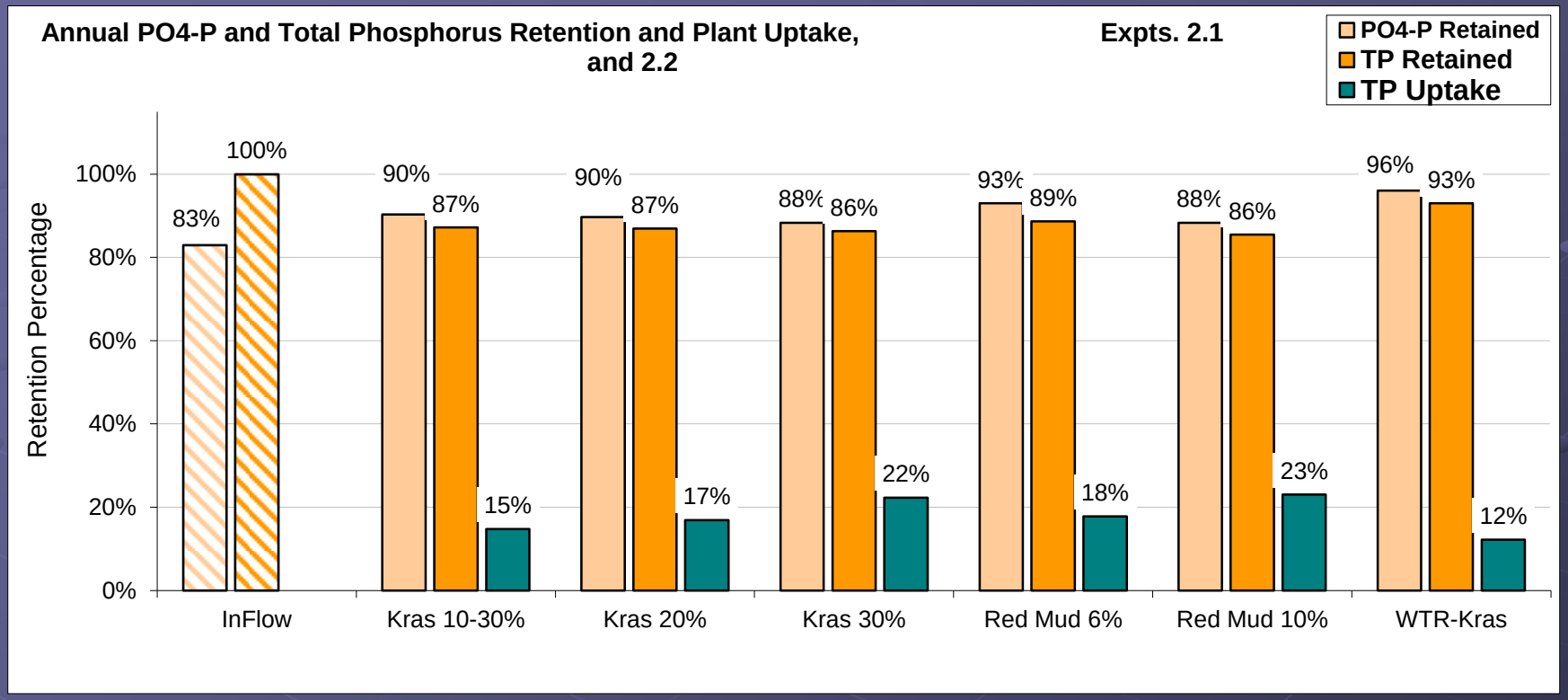
Grass*: Pennisetum alopecuroides*
Sedges: *Carex appressa; Isolepis nodosa*
Shrubs *: Callistemon pachyphyllus; Melaleuca thymifolia*

Expt 2 Shoot/Root Biomass after 3 years



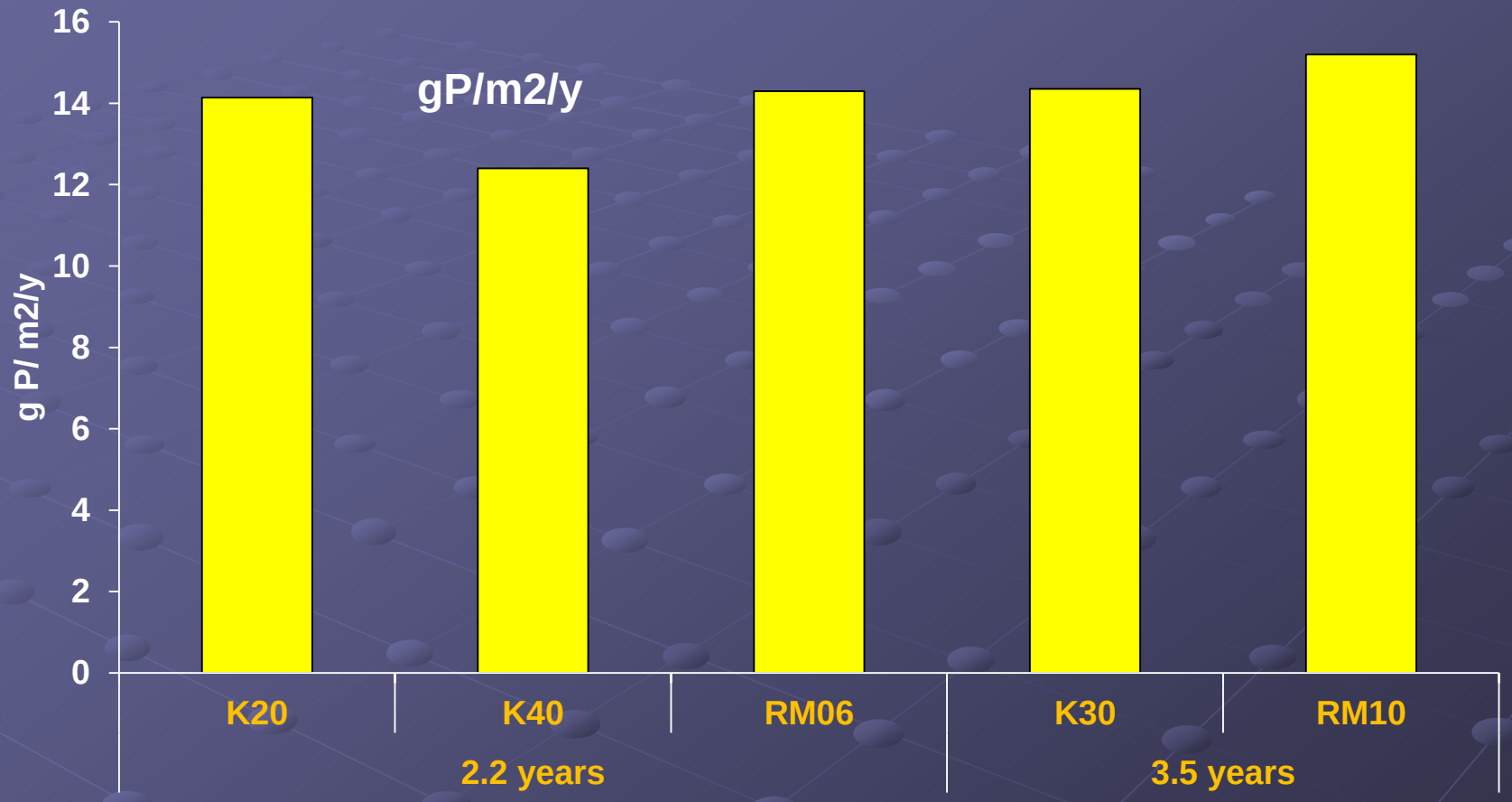
- Pennisetum had the highest biomass (cropping of shoots)
- Isolepis had poorest root biomass- ‘wiry’ morphology / competition ?

Expt 2 % phosphorus retention & TP plant uptake (mass load– 200gP/m2)



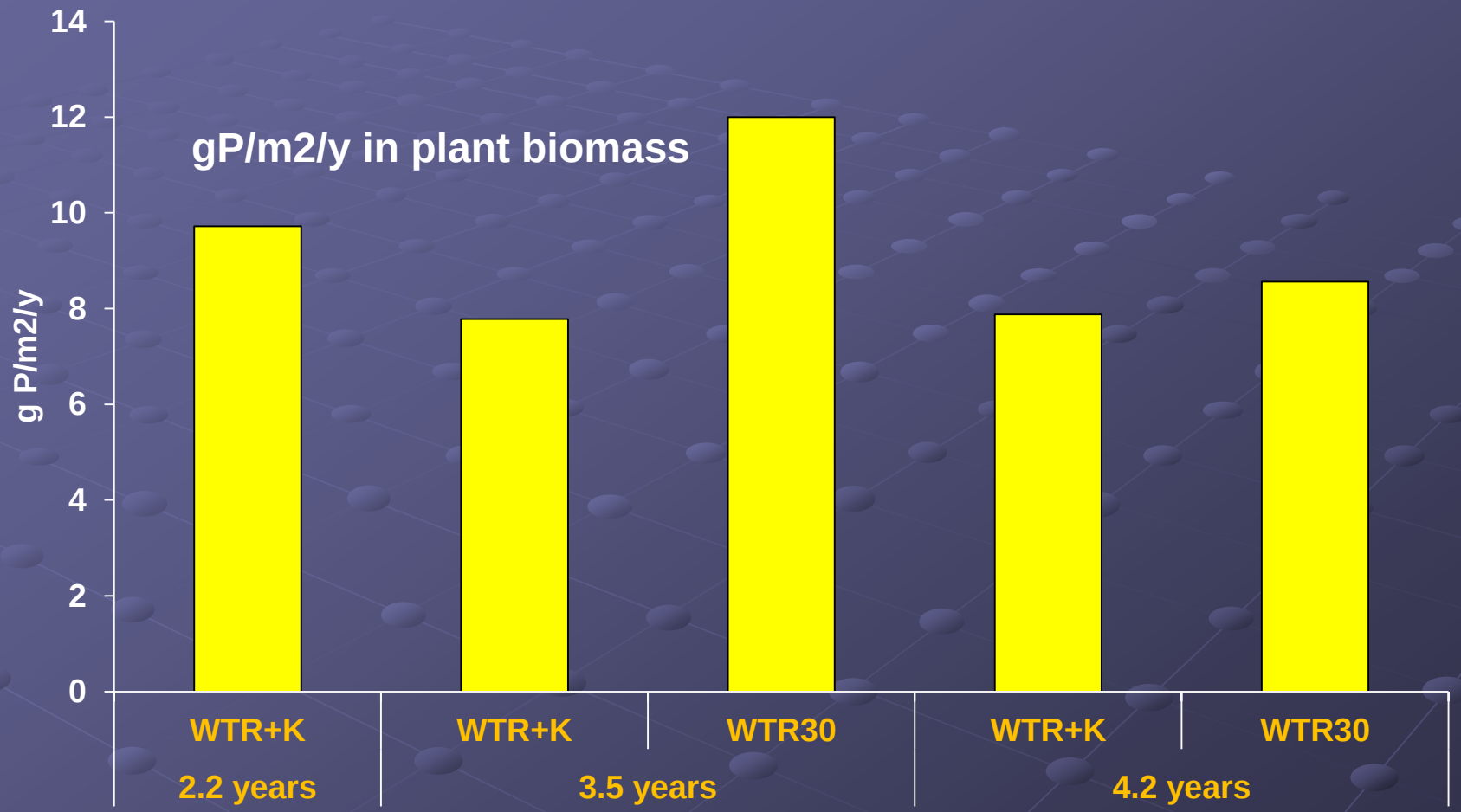
- All media excellent P retention (85-96%)- no indication of P saturation even after total inflow loads of 300gP/m2
- Retention far exceeded plant uptake (note lower % due to higher load)
- Media adsorption primary P removal process

Annual P accumulation in plant biomass in media with Krasnozems and Red Mud



Annual P uptake 12-14g/m2 K treatments and 14-15g/ m2 RM treatments

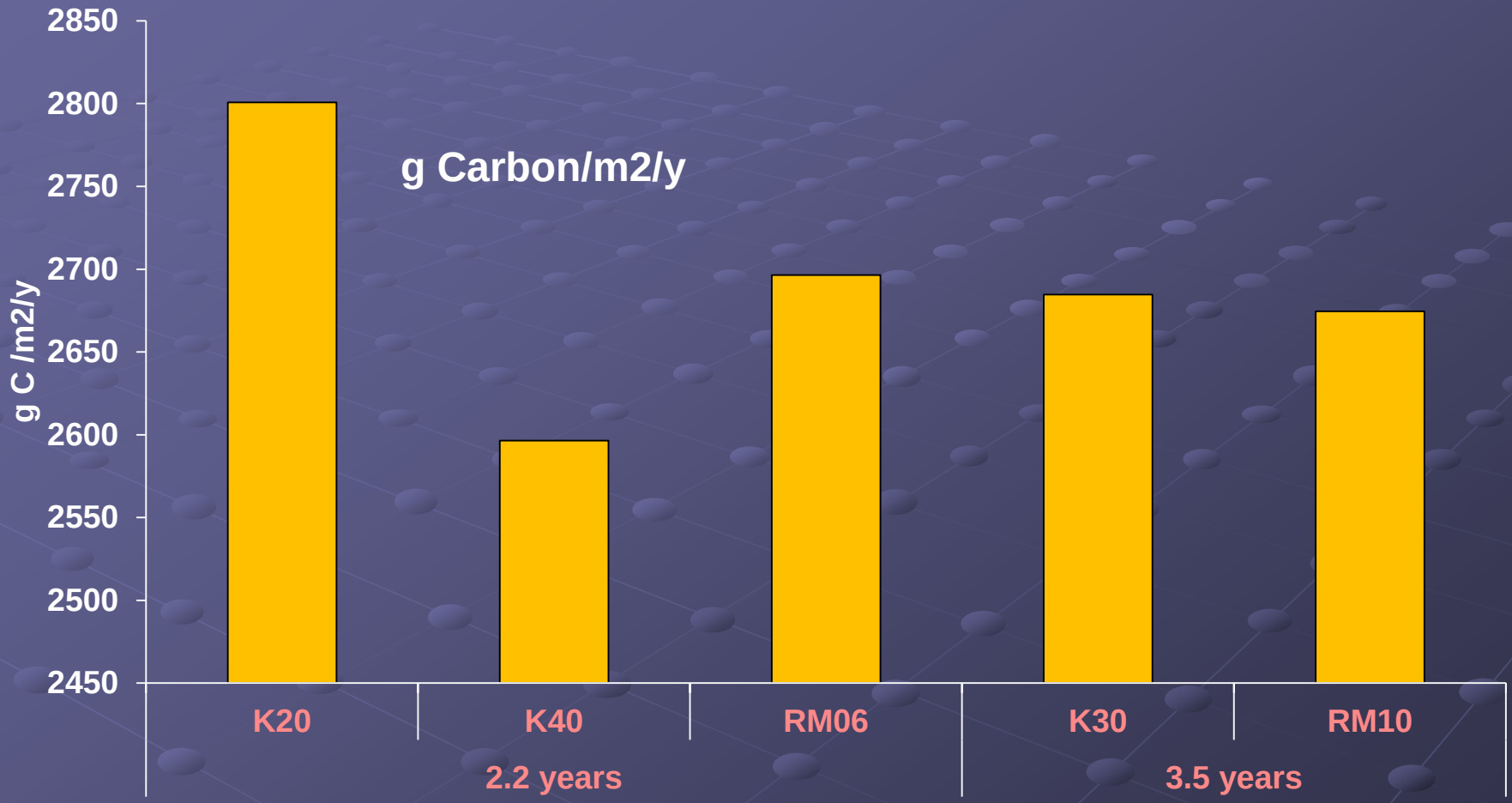
Annual P accumulation in plant biomass in media with Water Treatment Residuals and Krasnozems



Annual P uptake 10g/m2 WTR+K and 12g/ m2 WTR30

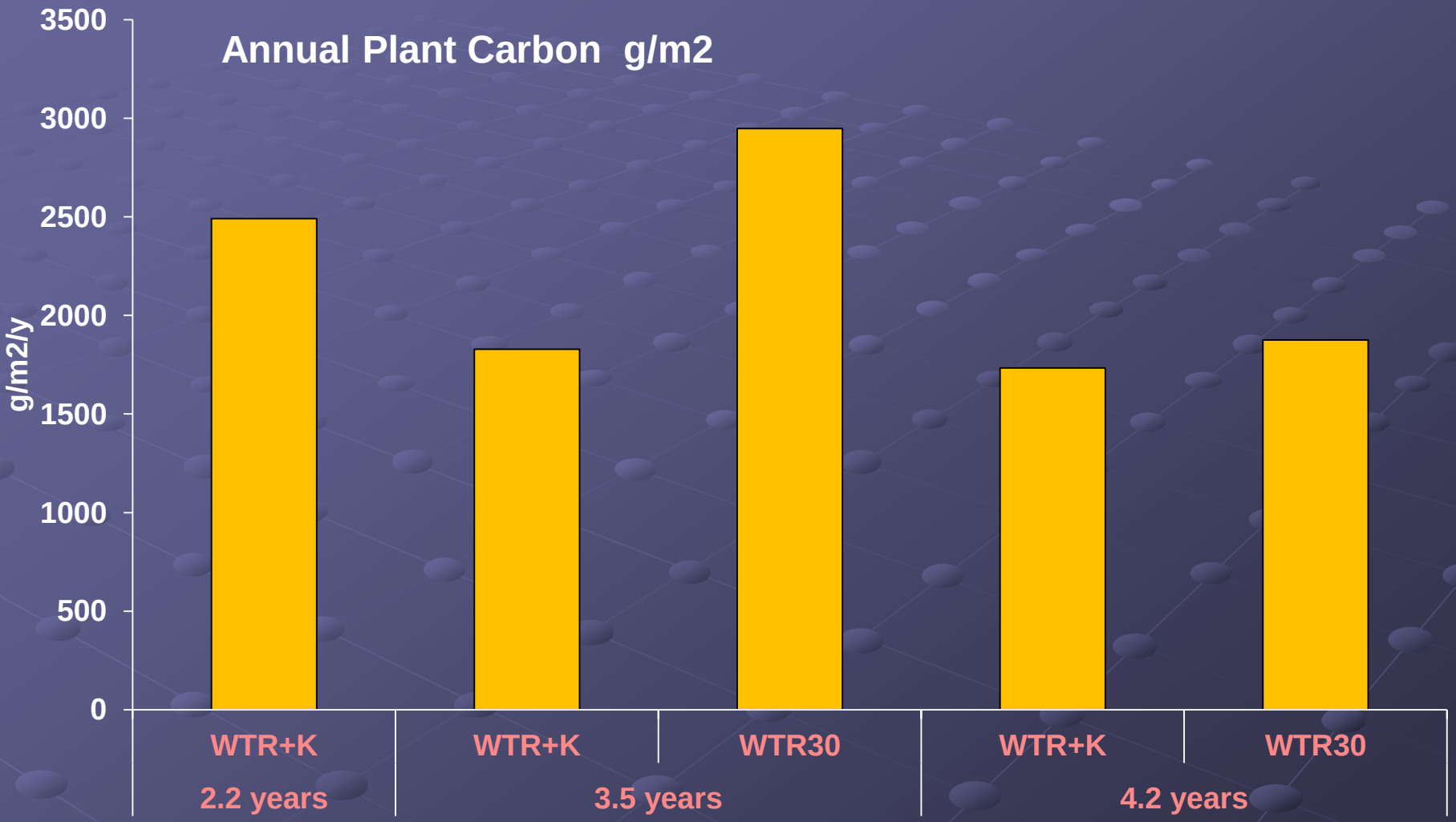
Annual P accumulation decreased over time as plants became pot bound

Annual Carbon accumulation in plant biomass in media with Krasnozems and Red Mud



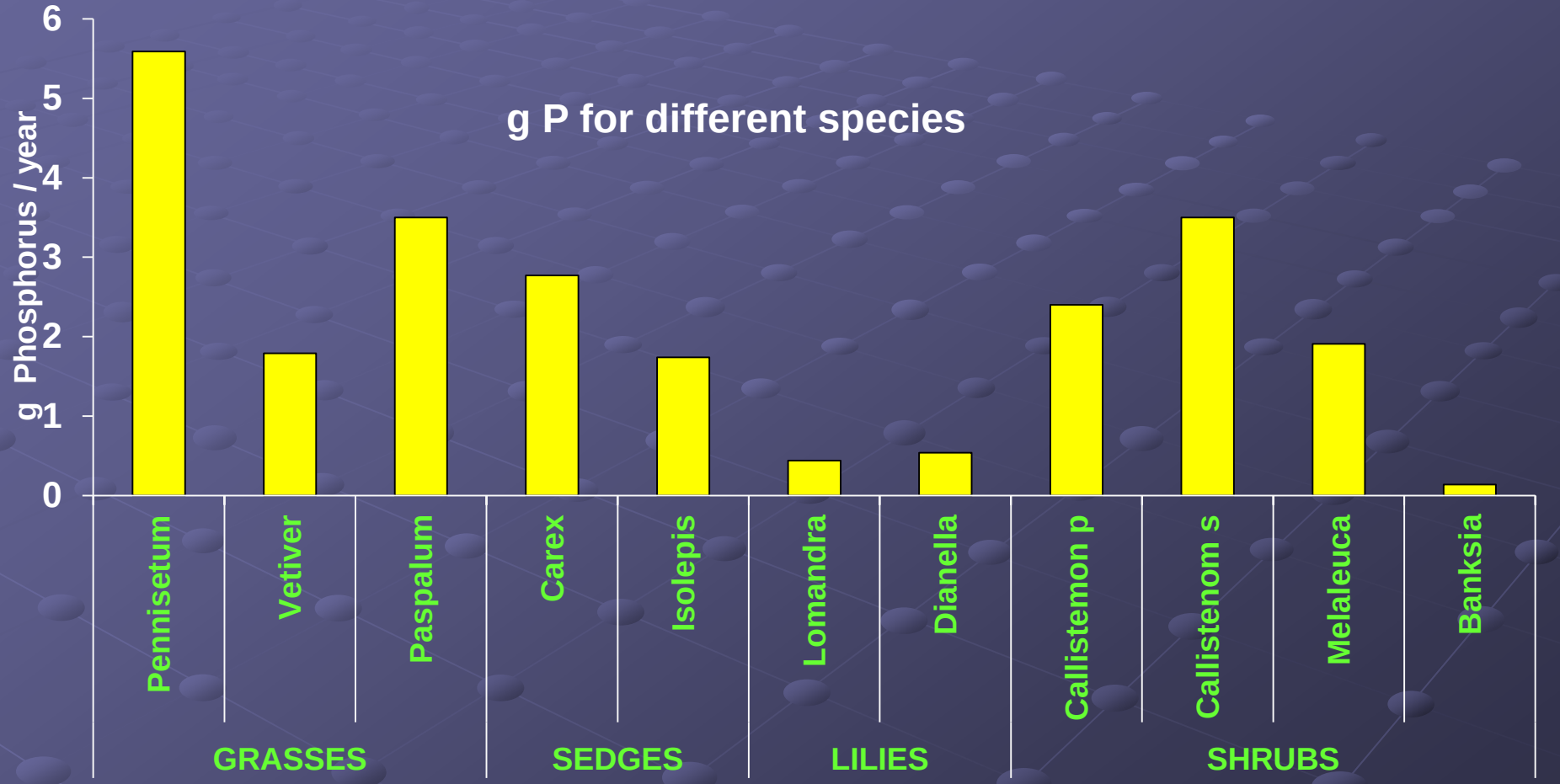
Annual carbon accumulation ranged from 2800g (K20) to 2600g (K40) m2/y

Annual Carbon accumulation in plant biomass in media with WTR and WTR + K

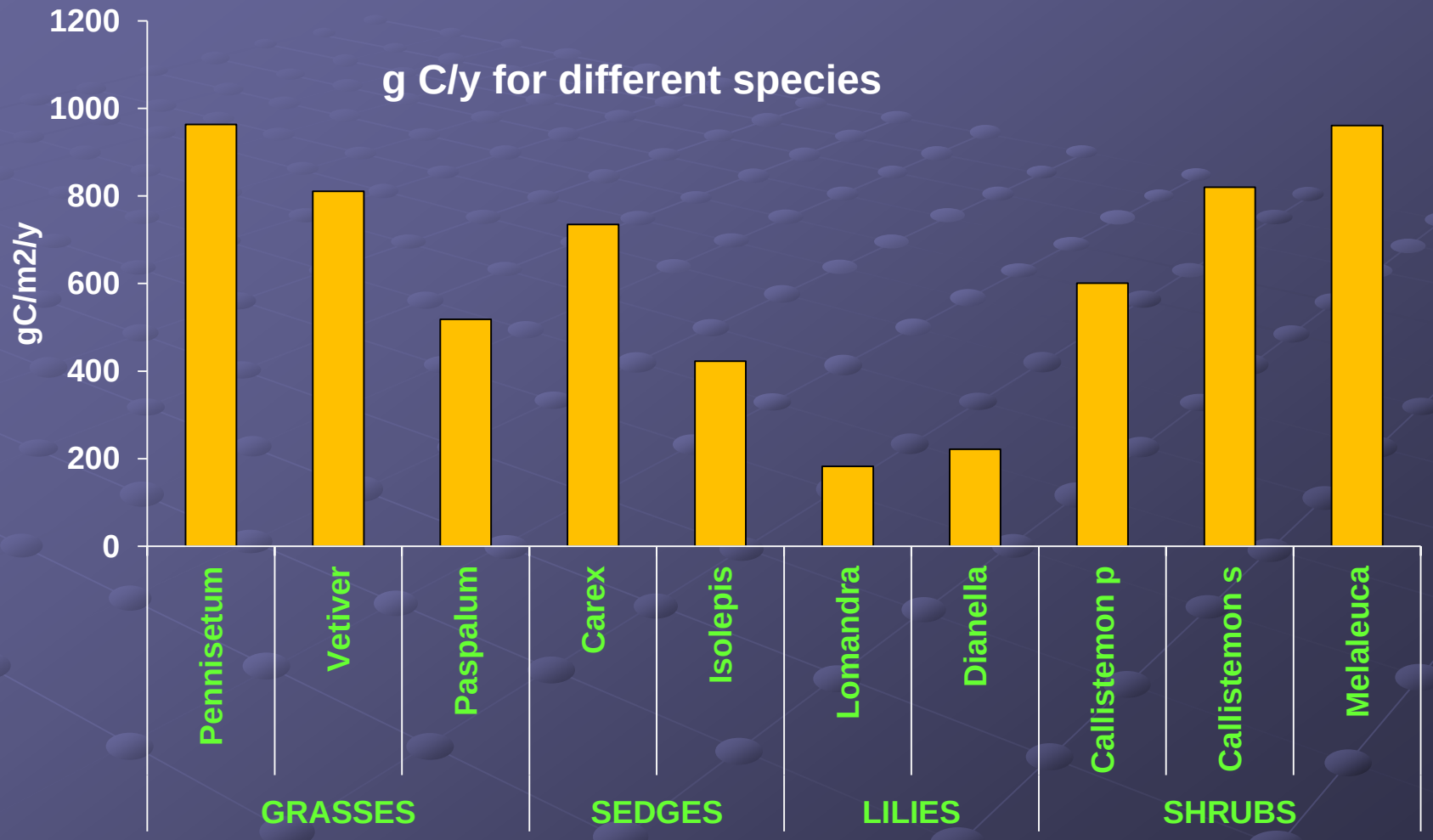


Annual carbon accumulation up to 3000 g/m2/y (WTR 30)

Annual P accumulation in plant species biomass after 2 years



Annual Carbon accumulation in plant species biomass after 2 years



Conclusions- Media Retention Phosphorus

- Mesocosms with sandy media amended with Krasnozem soils, Red Mud, and Water Treatment Residuals ALL demonstrated excellent P retention from wastewater effluent.
- Sand amended with Water Treatment Residuals was the most effective treatment - 99% retention, and showed no sign of saturation even after the application of 4000kgP/ha

Thus all our amended sand media demonstrated long term capacity for P sorption and retention.

Conclusions - Plants

- Pennisetum and Carex yielded the highest biomass of the herbaceous plants.
- Harvesting of the shoots increased yield –but this requires maintenance.
- Callistemon and Melaleuca yielded the highest biomass of the woody plants.
- All plants trialed grew equally well in our media.
- Plants are not only effective in Phosphorus (& N) uptake but also sequester Carbon

Thus the selection of suitable plant species is paramount for long term sustainability of wetlands and bioretention systems.

Thank You

Green tree frog finds a home in the wheelie bin mesocosm

First Announcement and Call for Abstracts

Murdoch
UNIVERSITY

13th International Conference in Wetland Systems for Water Pollution Control

25-29 November 2012

The biennial meeting of the IWA Specialist Group on the Use of Macrophytes in Water Pollution Control

Hosted and Organised by

Murdoch University
Perth, Western Australia

in collaboration with IWA and AWA

International Water Association

AWA