Smart Farming-Based Efficient Nutrient Management: Increasing Sugarcane Productivity through Elemental Tracer and Related Techniques

PNRI SRA PCAARRD

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Objectives

To increase the nutrient utilization efficiency in sugarcane production through nutrient management using elemental tracer and related techniques.

Objectives

Specifically the research aims:

1. To elucidate and delineate nutrient utilization dynamics (NUD) of sugarcane as enhanced by stable isotope tracer and related techniques;

2. To determine cane yield response to different levels of fertility to further refine fertilizer recommendation based on nutrient use efficiency (NUE) and NUD.

IAEA RAS 5/070 project entitled “Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques”was linked to this national project

- To further maximize the use of the sugarcane by products and residues like the sugarcane bagasse for bioenergy.
- Sugarcane variety adopted and popular to the different sugarcane plantation in the Philippines was used in the study for updating fertilizer recommendation and
- Conducted in one of the research station where deposits of ash falls during the Mt.Pinatubo eruption in 1991 made the sugarcane land in Pampanga as a problem soil (lahar laden).
- Updated fertilizer recommendation will be used for the field trial of the sugarcane variety developed through induced mutation breeding

Methodology

Experimental Site:

Luzon Agricultural Research and Extension Center (LAREC), Sugar Regulatory Administration (SRA)

Sugarcane variety: Phil 99-1793

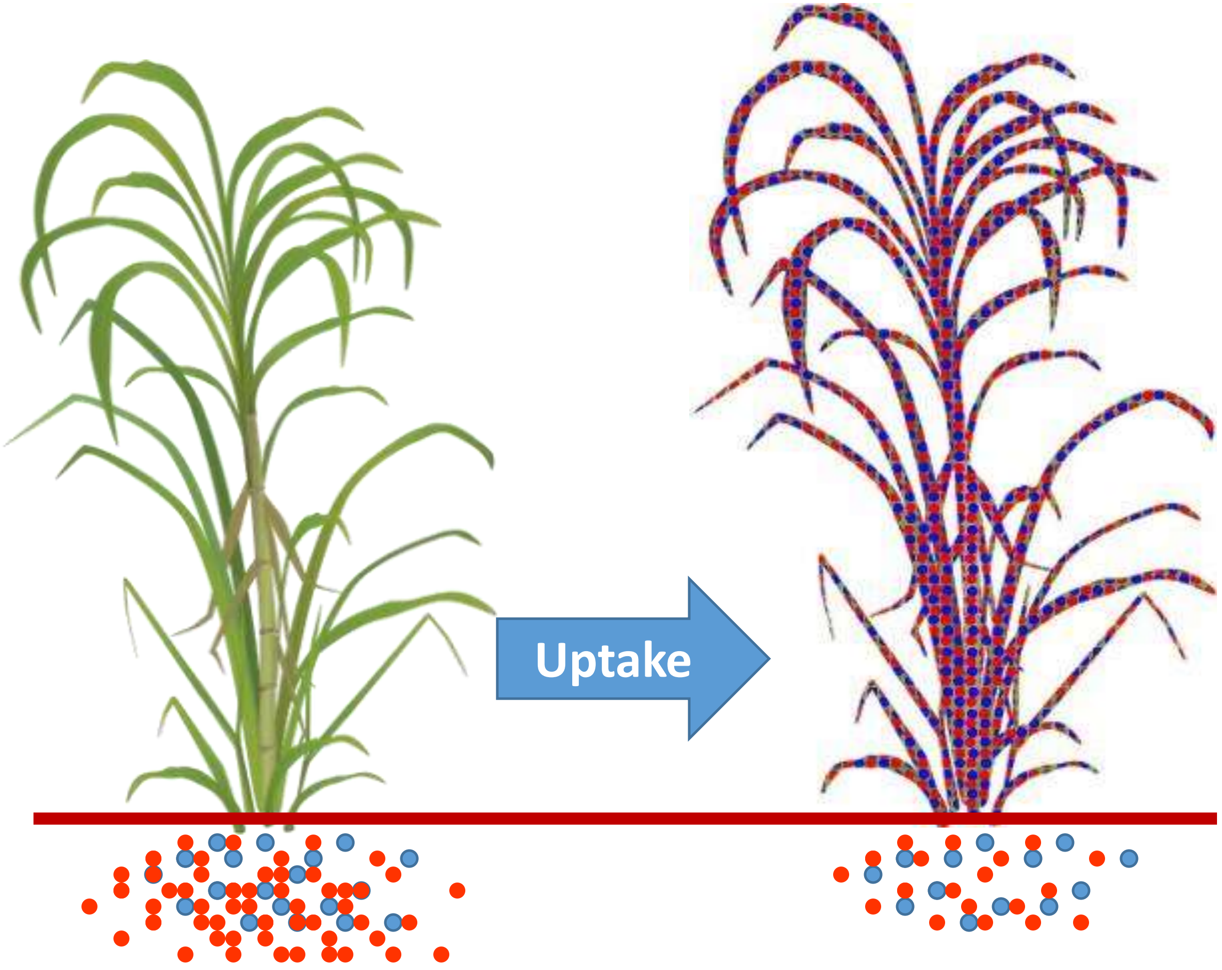
Experimental design: RCBD

Number of Replications: 4

Methodology

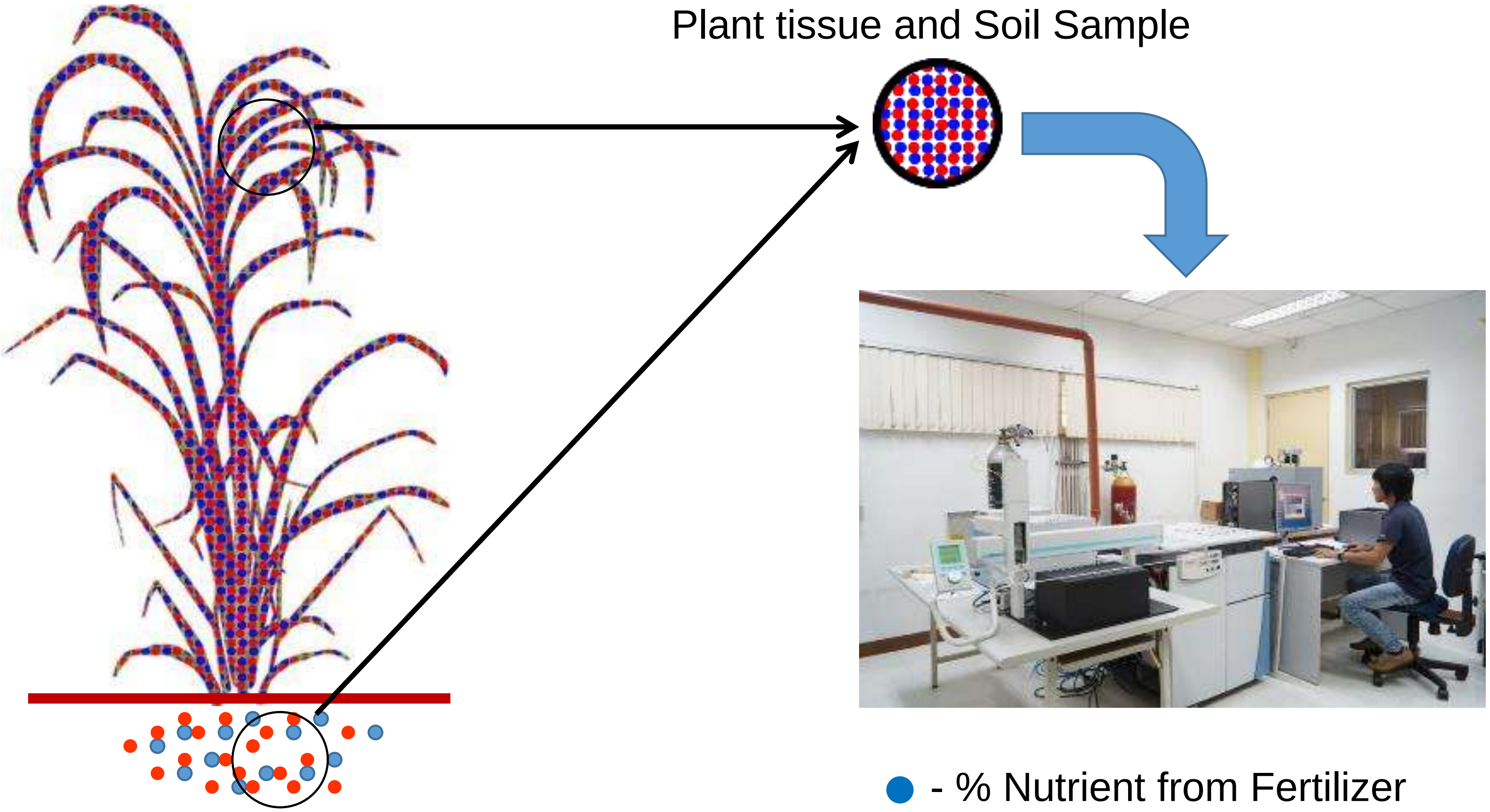
Field Experiment	Depth (cm)	pH (1:2.5)	OM (%)	Total N (%)	Available P (mg kg $^{-1}$)	Exchangeable K (mg kg $^{-1}$)	EC (µS cm $^{-1}$)
N	0-20	5.0	1.66	0.05	24.76	62.20	58.70
	20-40	5.59	1.28	0.06	12.49	38.18	38.00
P	0-20	4.67	1.80	0.06	32.45	50.14	70.90
	20-40	4.98	1.70	0.06	22.58	35.21	45.60
K	0-20	5.58	1.29	0.04	15.68	34.73	28.70
	20-40	6.08	1.70	0.05	8.66	33.61	36.00

Tracer technique



- Nutrient from Fertilizer
- Nutrient from SOM/Soil

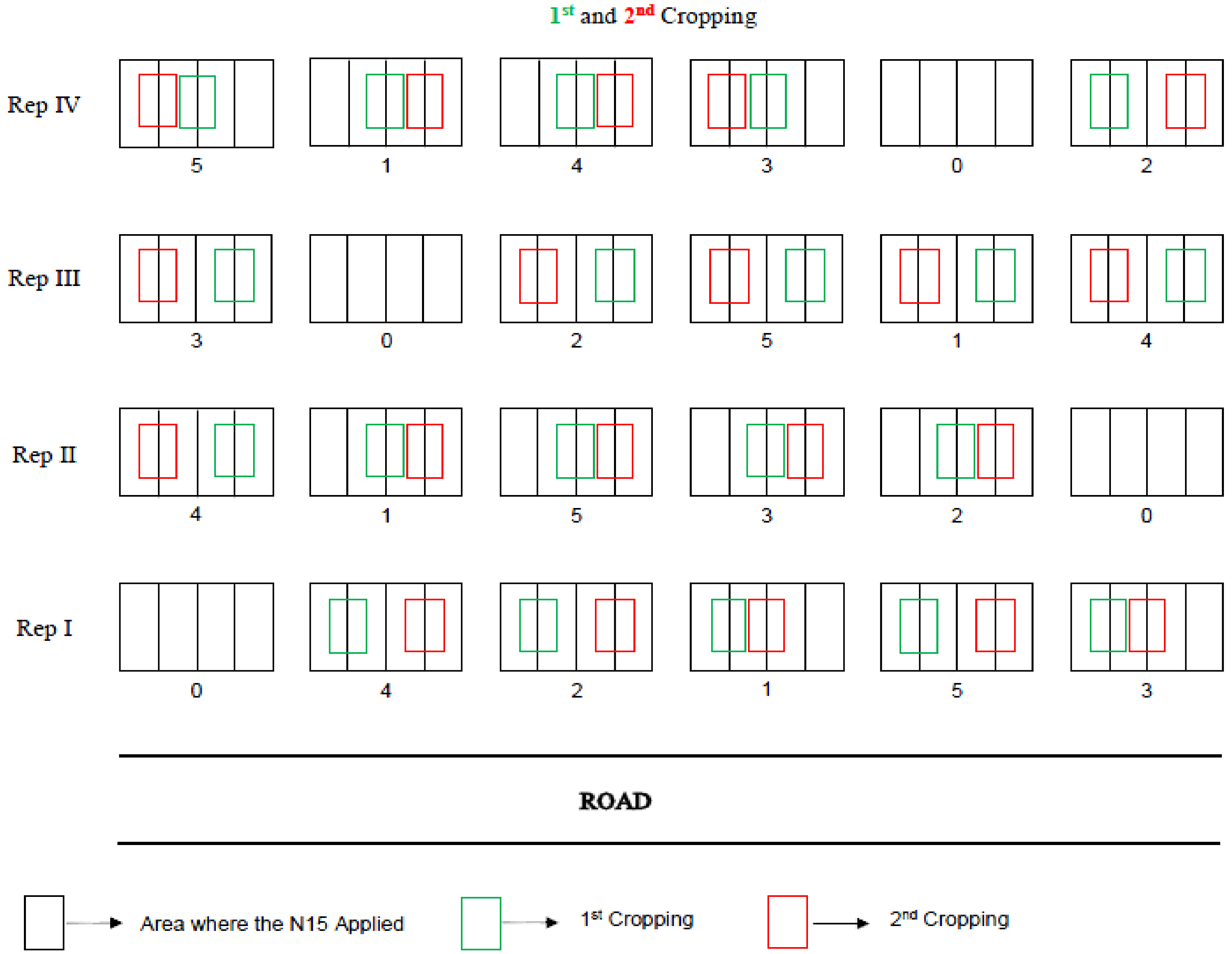
Tracer technique

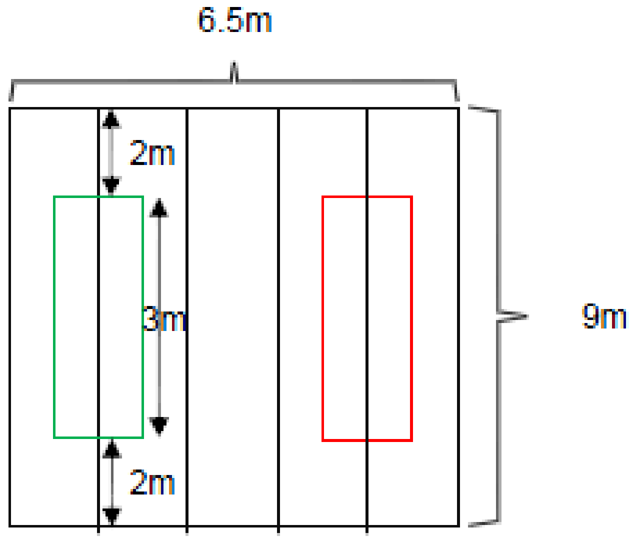


- Nutrient from Fertilizer
- Nutrient from SOM/Soil

- % Nutrient from Fertilizer
- % Nutrient from SOM/Soil

Tracer Microplot Layout





Actual area of plot in the field

Nitrogen Field Trial

Treatments (kg N/ha)

Control
T1 – 60
T2 – 120
T3 – 180
T4 – 240
T5 - 300

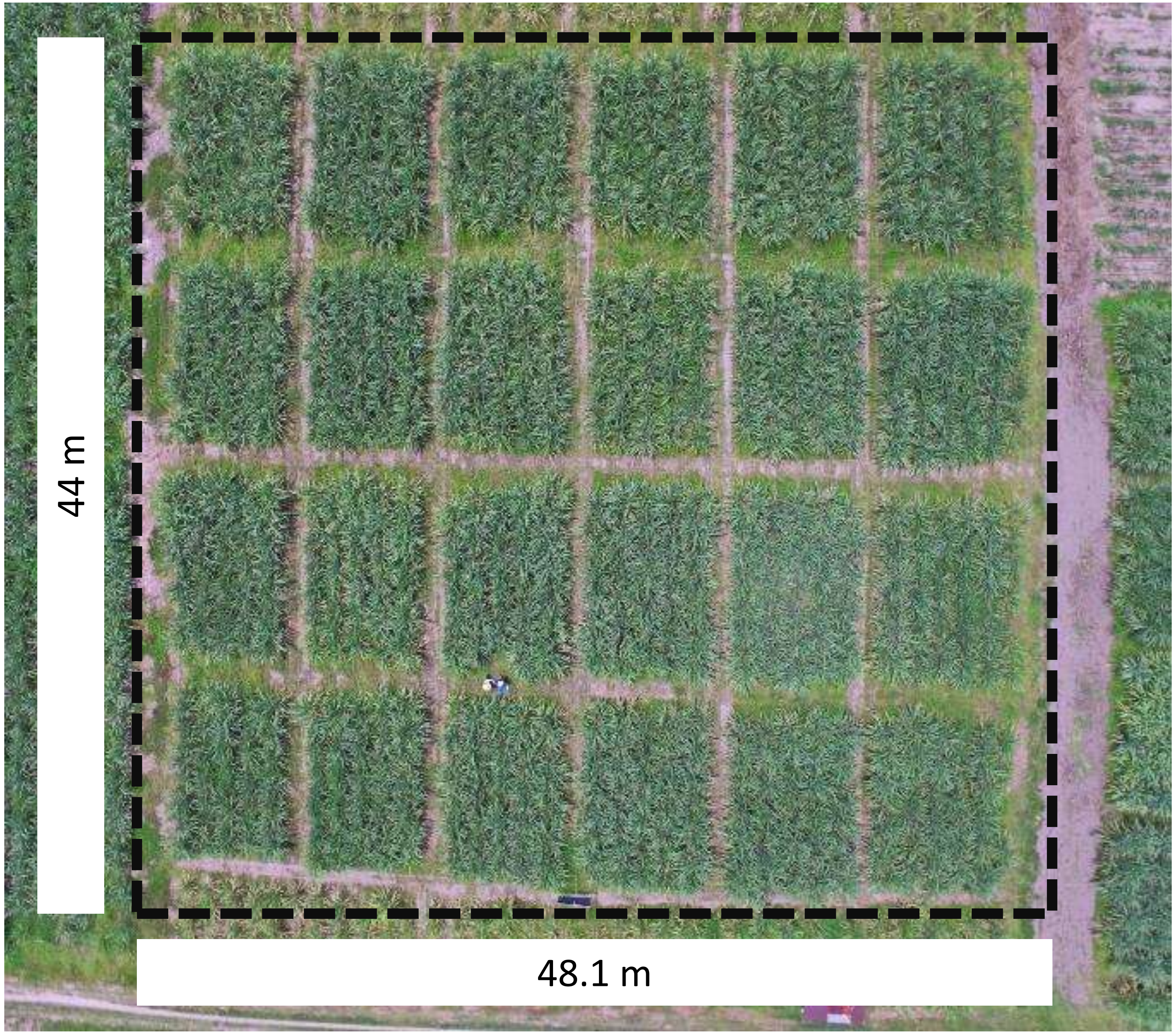
14° 59' 33.628800” N
120° 31' 43.970200” E
2116 m^2

PhosphorusField Trial

Treatments (kg N/ha)

Control
T1 – 60
T2 – 120
T3 – 180
T4 – 240
T5 - 300

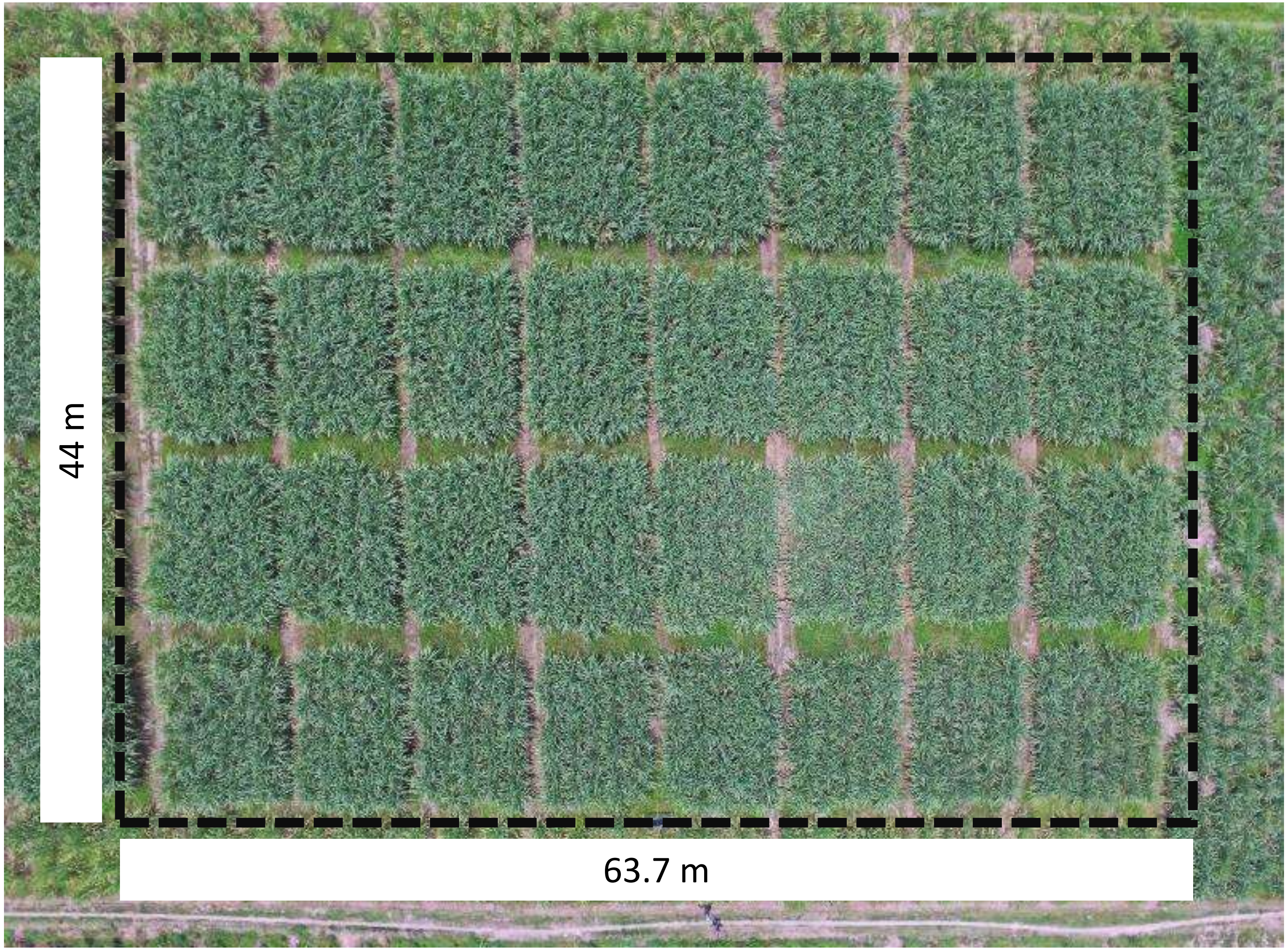
14° 59' 28.130000” N
120° 31' 41.463800” E
2116 m^2



Potassium Field Trial

Treatments (kg N/ha)
Control
T1 – 100
T2 – 200
T3 – 300
T4 – 400
T5 – 500
T6 – 600 T7 - 700

14° 59' 31.809000” N
120° 31' 43.130500” E
2803 m²



Accomplishments

Activities

2.0 ha Land preparation

planting

germination

Fertilizer preparation

Isotope labelled fertilizer

Fertilizer application

Chlorophyll monitoring

Laboratory analysis

Installation of soil moisture monitoring sensors

Soil sampling

10HS calibration with SMNP

Downloading moisture data

Drilling for leachate sampling

Freezing leachate samples in LN2

Stalk diameter measurements

Dew lap height measurement

HA cane weight

Cane Juice Extraction

Brix analysis

Sample preparation

Fine grinding



Clearing of weeds (Tractor driven and gasoline grass cutter)


Soil and Plant Tissue nutrient analysis

Tracer Analysis

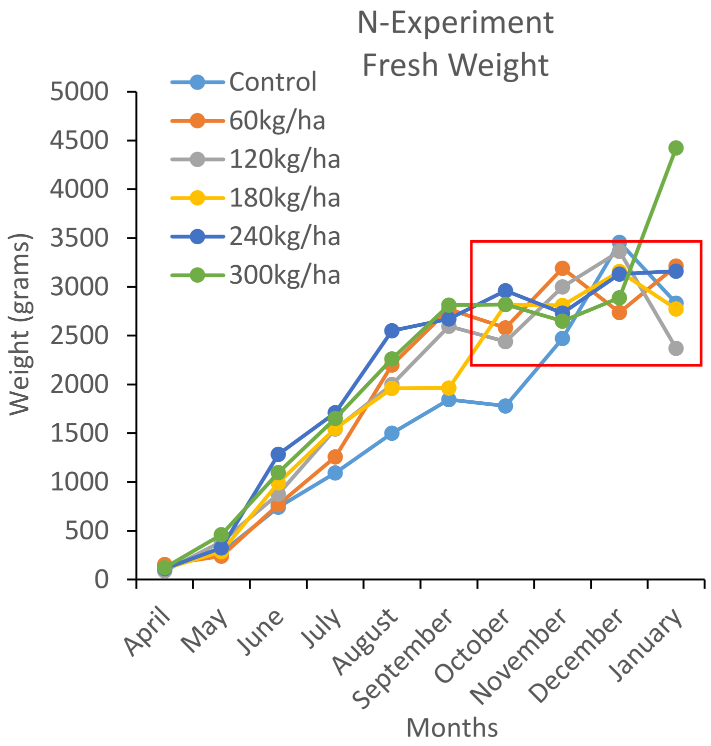
Accomplishments

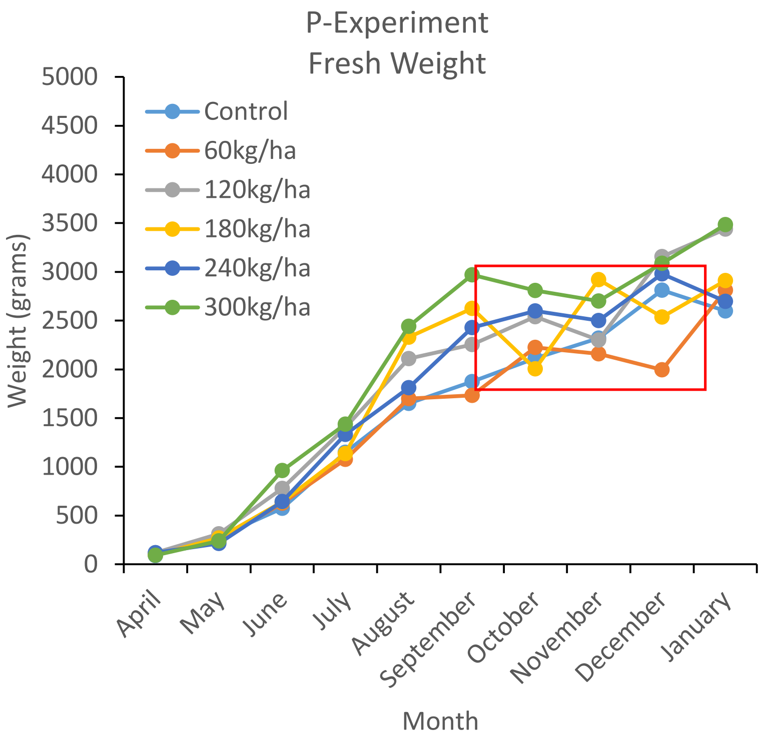
Data

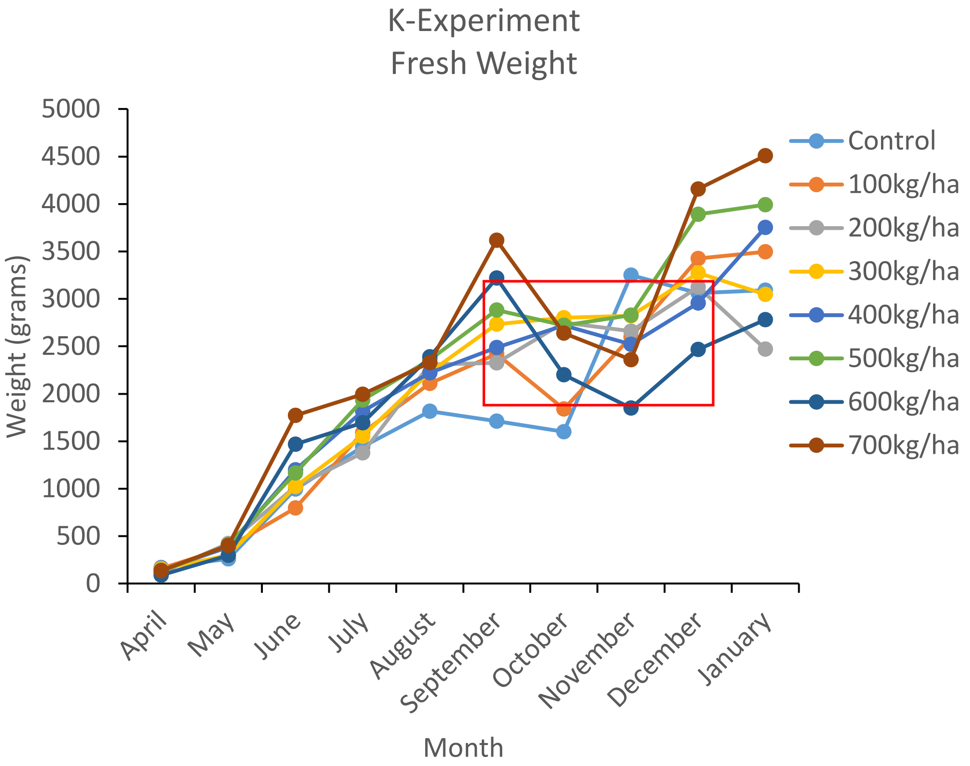
Soil Moisture Profile

Upper 60 cm was very dynamic and fluctuated easily with time. This may explain that the effective rooting depth of sugarcane crops falls on this depth. Likewise, it can be considered that at this depth is also zone of active nutrient absorption by the roots. Additionally, considerable fluctuations occur at the upper most 20 cm from the soil surface. This may be due to the active capillary movement of water and through evaporative loss near the soil surface

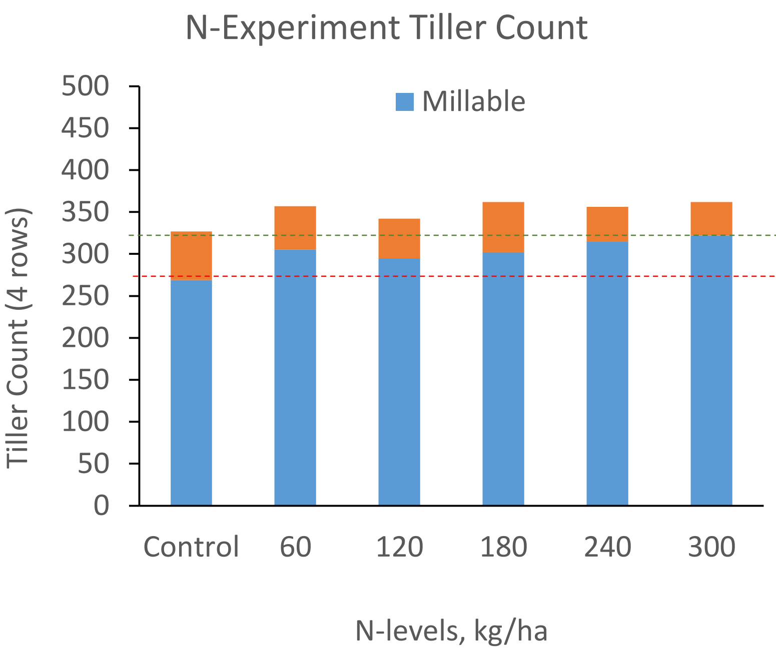
Sugarcane Fresh Weight

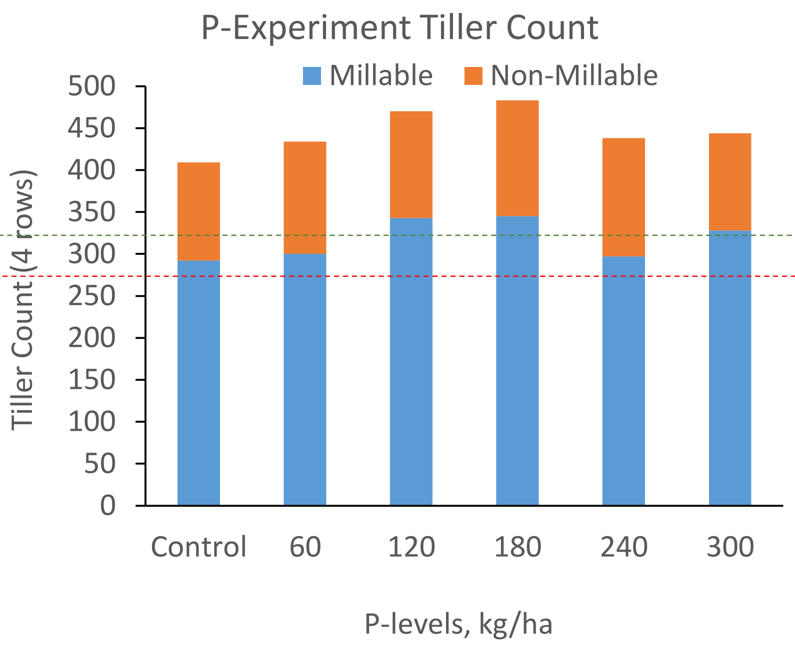


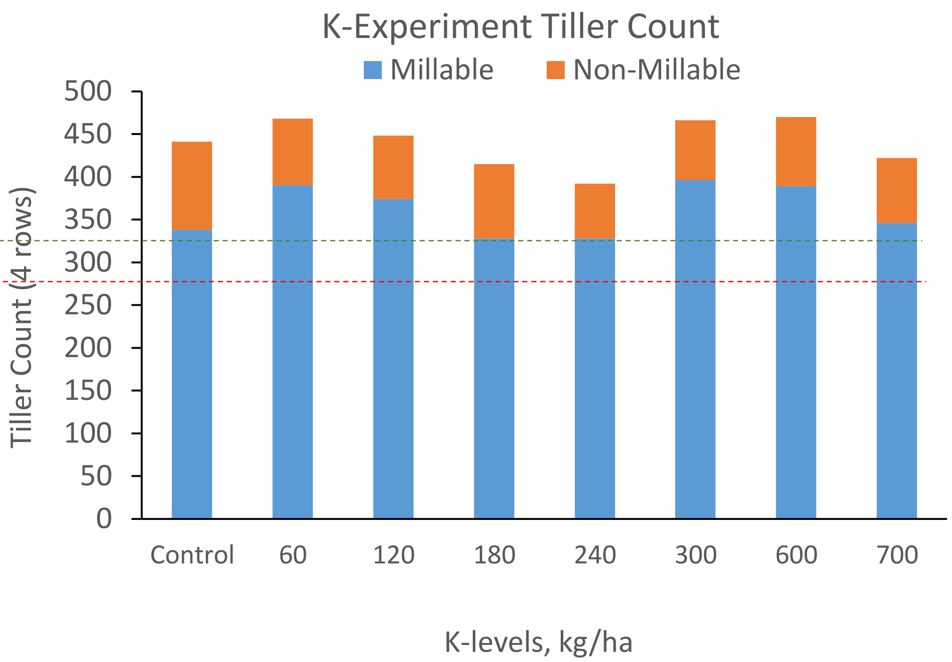




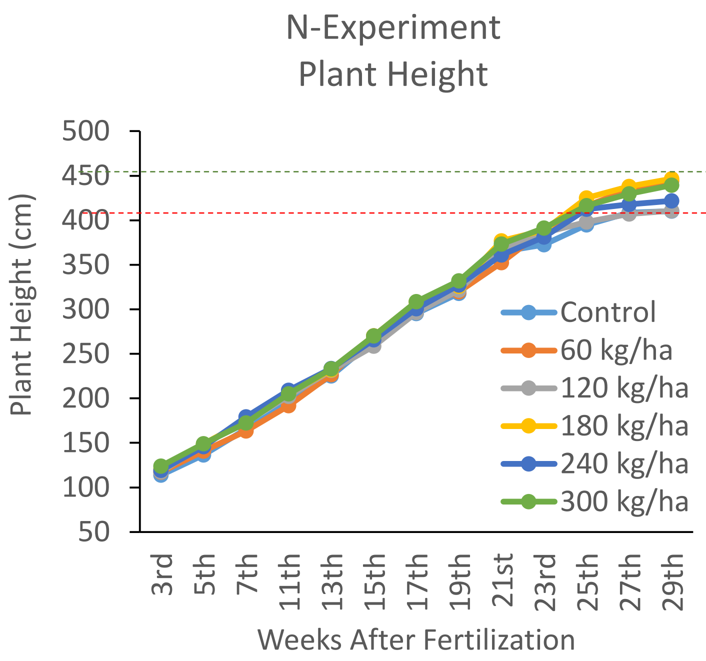
Sugarcane Tiller Count

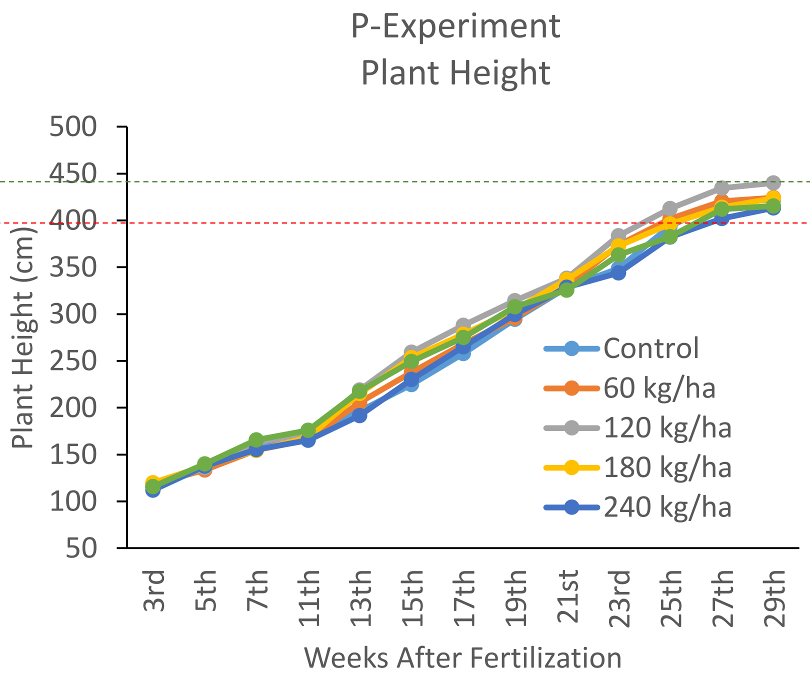


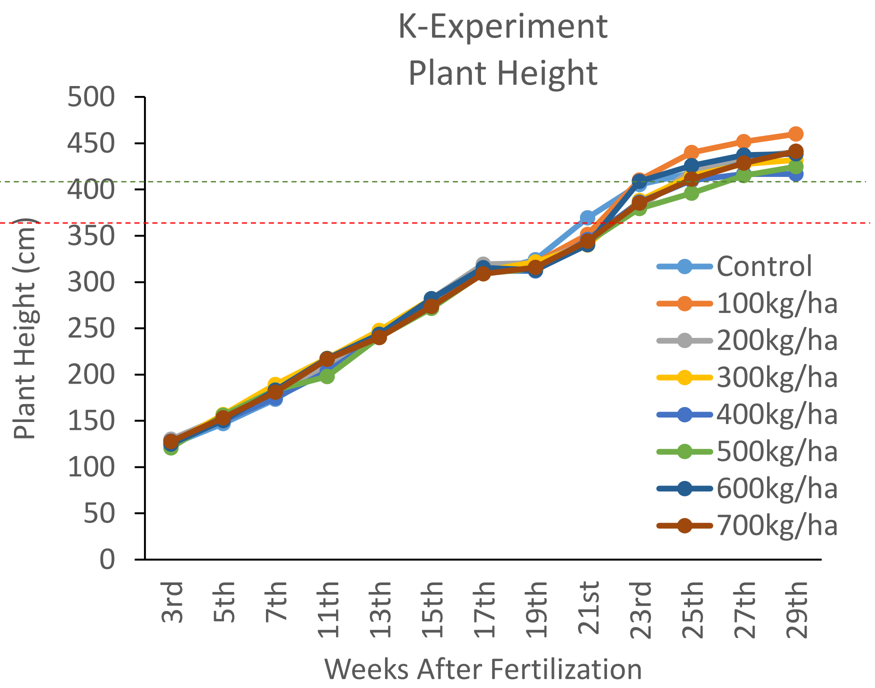




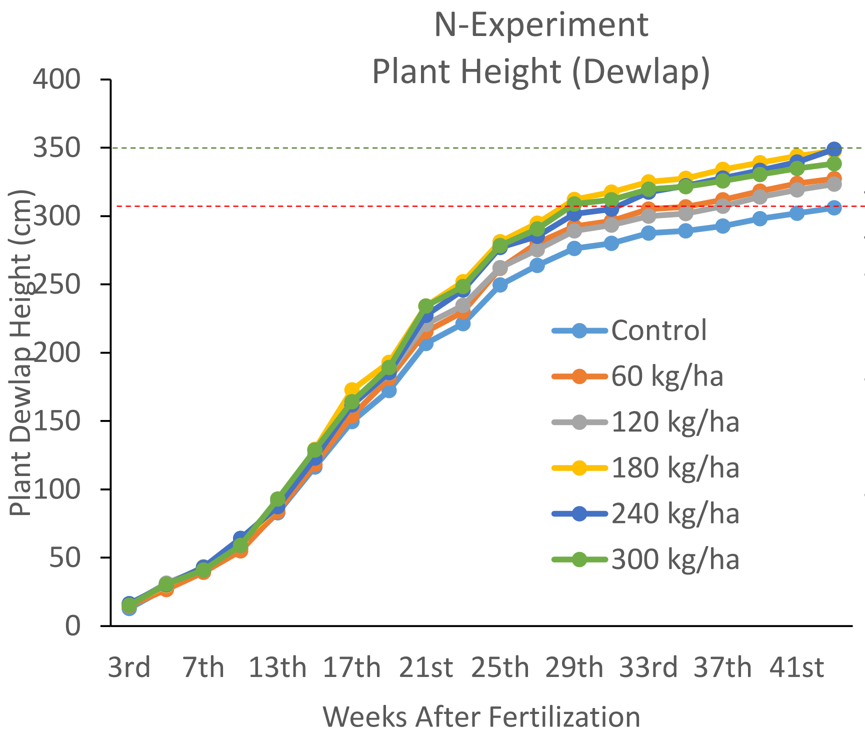
Sugarcane Plant Height (Leaf tip)

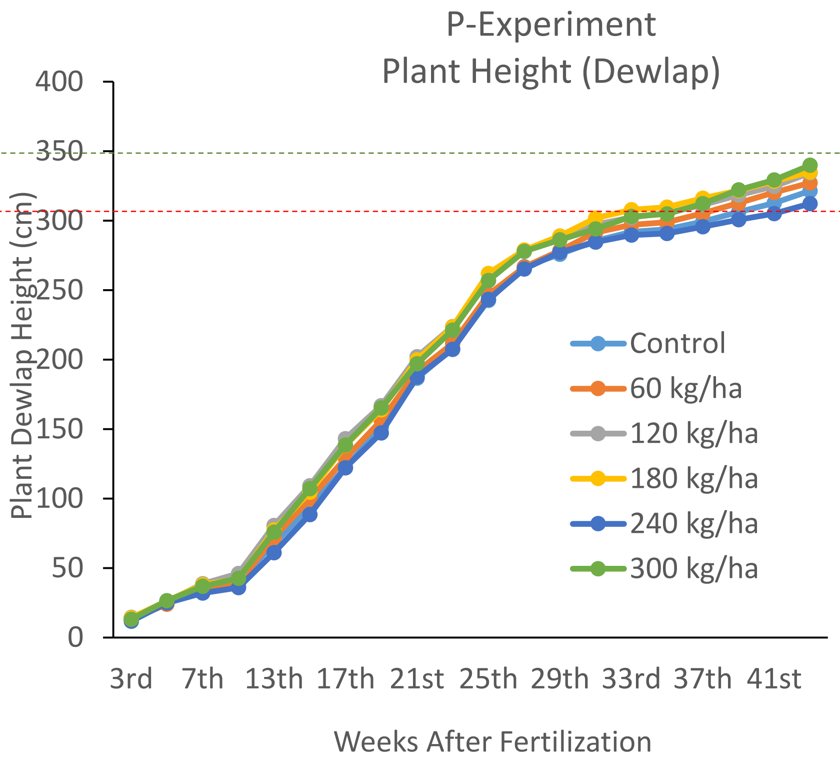


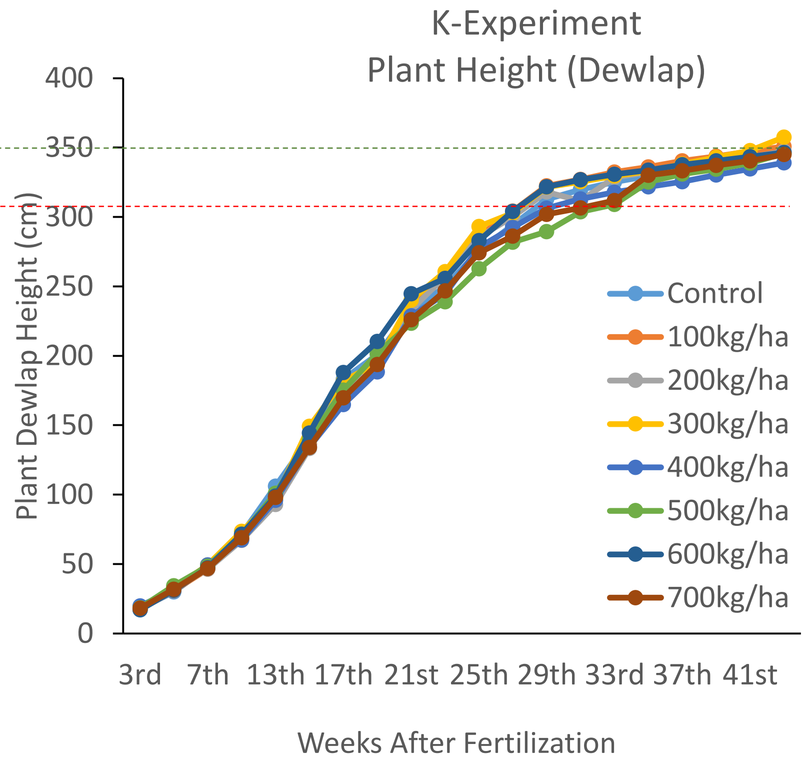




Sugarcane Plant Height (Last dewlap)







Sugarcane Leaf Chlorophyll (SPAD Units)

Nitrogen Field Trial

Treatment (kg N/ha)	Chlorophyll Meter (SU)	
	7 MAP	Harvest
Control	48.6^{d}	31.1
60	51.1^{c}	30.8
120	52.6^{b}	31.3
180	52.7^{b}	31.6
240	54.9^{a}	32.2
300	55.7^{a}	32.0

PhosphorusField Trial

Treatment (kg P_2O_5/ha)	Chlorophyll Meter (SU)	
	7 MAP	Harvest
Control	49.3^{e}	30.2
60	52.1^{d}	31.1
120	52.4^{cd}	26.9
180	53.6^{bc}	27.8
240	53.9^{bc}	29.0
300	55.2^{a}	28.5

Means with common letter(s) within the same column and treatment group are not significantly different at 5% level of significance based on LSD.

Minolta SPAD 502 Chlorophyll meter was used to measure the relative chlorophyll content of the fully expanded functional sugarcane leaf.

Sugarcane Leaf Chlorophyll (SPAD Units)

Potassium Field Trial

Treatment (kg K_2O/ha)	Chlorophyll Meter (SU)	
	7 MAP	Harvest
Control	49.4 [d]	31.7
100	51.1 [c]	32.8
200	52.0 [bc]	30.6
300	52.3 [abc]	34.2
400	52.8 [abc]	29.9
500	53.7 [ab]	32.8
600	53.6 [ab]	30.4
700	54.0 [a]	32.8

Means with common letter(s) within the same column and treatment group are not significantly different at 5% level of significance based on LSD.

Sugarcane Data (N-Experiment)

Treatment	Stalk Diameter (mm)			Plant Height (cm)	Millable Stalk (Stalk/ha)	Fresh Weight 10 Stalks	Lkg/TC
	Base	Middle	Top				
control	31.05^{ab}	29.08^{bc}	27.80^{ab}	320.68	71813	21.81^{c}	1.86
60	30.75^{b}	28.80^{c}	27.13^{b}	320.58	74359	21.71^{c}	1.93
120	31.33^{ab}	29.95^{ab}	27.98^{ab}	329.38	74288	23.93^{bc}	1.88
180	31.58^{ab}	29.73^{abc}	27.18^{ab}	322.95	71154	25.44^{b}	1.94
240	32.18^{a}	30.58^{a}	28.65^{a}	323.88	69786	25.25^{b}	1.84
300	31.83^{ab}	30.53^{a}	28.53^{ab}	338.45	71368	28.40^{a}	1.87

Means with common letter(s) within the same column and treatment group are not significantly different at 5% level of significance based on LSD.

Sugarcane Data (P-Experiment)

Treatment	Stalk Diameter (mm)			Plant Height (cm)	Millable Stalk (Stalk/ha)	Fresh Weight 10 Stalks	Lkg/TC
	Base	Middle	Top				
control	30.58 ab	29.33 ab	27.30 ab	298.60 bc	64672 b	21.88 c	1.97 ab
60	31.70 a	30.30 a	27.55 ab	310.60 bc	66737 ab	22.90 bc	1.90 b
120	31.03 ab	29.05 ab	25.95 b	323.58 ab	65954 ab	23.28 bc	1.92 ab
180	31.23 ab	29.60 ab	27.88 a	286.73 c	71082 a	22.25 c	2.02 ab
240	30.45 b	28.83 b	26.73 ab	306.05 bc	66595 ab	24.58 b	2.08 a
300	31.73 a	29.25 ab	28.50 a	348.45 a	67165 ab	27.15 a	1.90 b

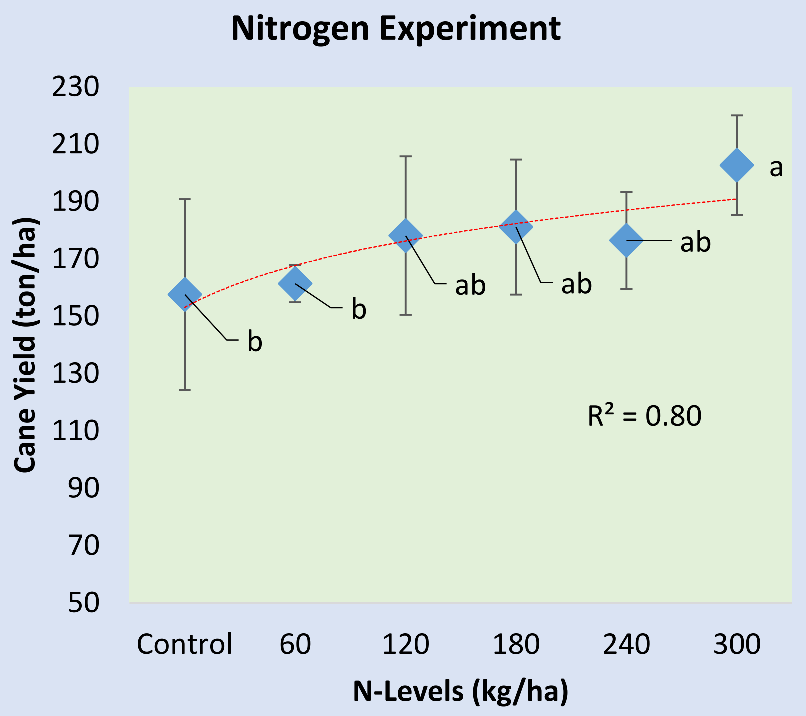
Means with common letter(s) within the same column and treatment group are not significantly different at 5% level of significance based on LSD.

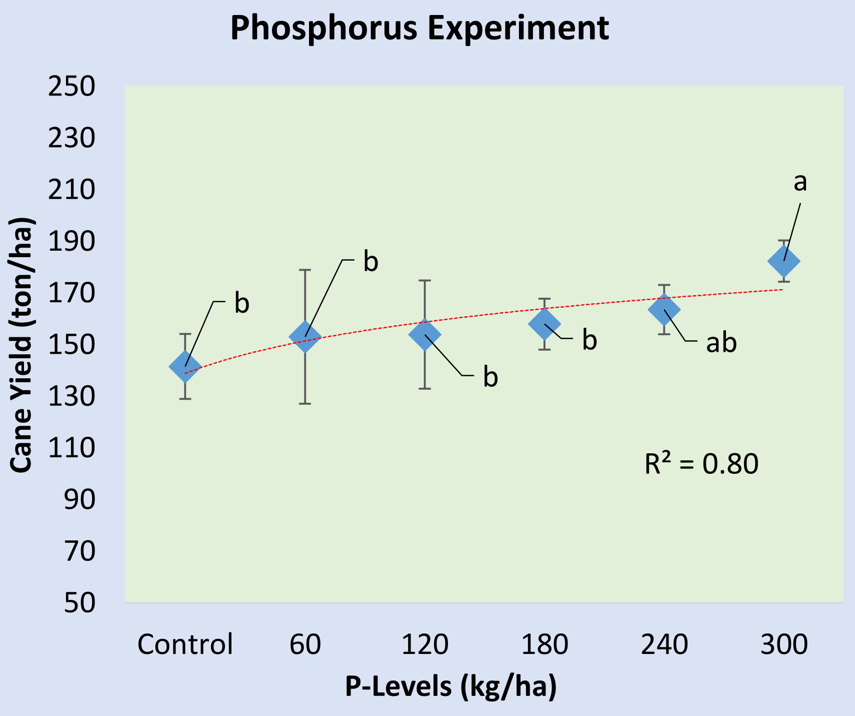
Sugarcane Data (K-Experiment)

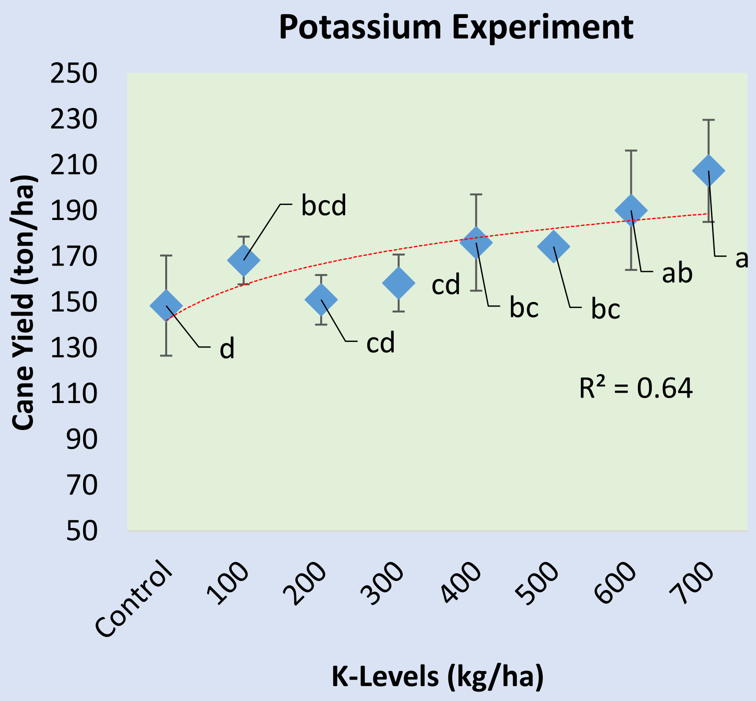
Treatment	Stalk Diameter (mm)			Plant Height (cm)	Millable Stalk (Stalk/ha)	Fresh Weight 10 Stalks	Lkg/TC
	Base	Middle	Top				
control	30.10^{d}	28.38^{c}	25.85^{c}	312.83^{bc}	70584.08	20.98^{e}	1.92
100	30.30^{cd}	28.48^{c}	27.43^{ab}	331.35^{ab}	68803.45	24.48^{bc}	1.81
200	30.70^{bcd}	28.78^{bc}	26.38^{bc}	316.23^{bc}	70512.85	21.45^{de}	1.89
300	31.23^{abcd}	29.33^{abc}	26.48^{bc}	310.28^{c}	69444.48	22.83^{cd}	1.81
400	31.33^{abc}	30.08^{a}	27.50^{ab}	326.30^{abc}	73717.98	23.88^{c}	1.80
500	30.73^{bcd}	28.83^{bc}	27.20^{ab}	314.45^{bc}	75000.03	23.35^{c}	1.89
600	31.75^{ab}	29.78^{ab}	27.45^{ab}	324.75^{abc}	73931.65	25.80^{b}	1.89
700	32.28^{a}	30.50^{a}	28.00^{a}	341.00^{a}	73076.95	28.38^{a}	1.90

Means with common letter(s) within the same column and treatment group are not significantly different at 5% level of significance based on LSD.

Sugarcane Yield







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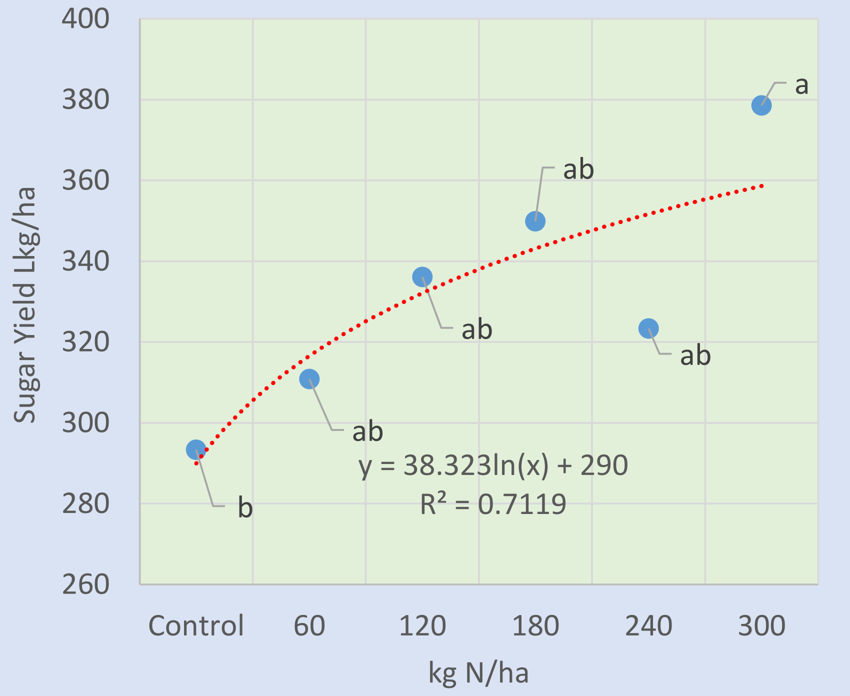
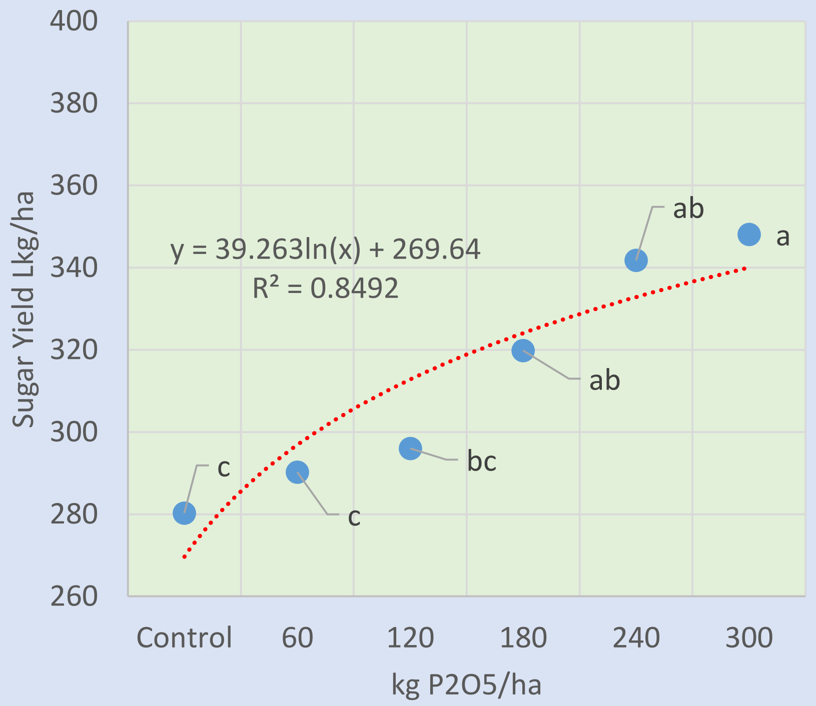
Sugar Yield

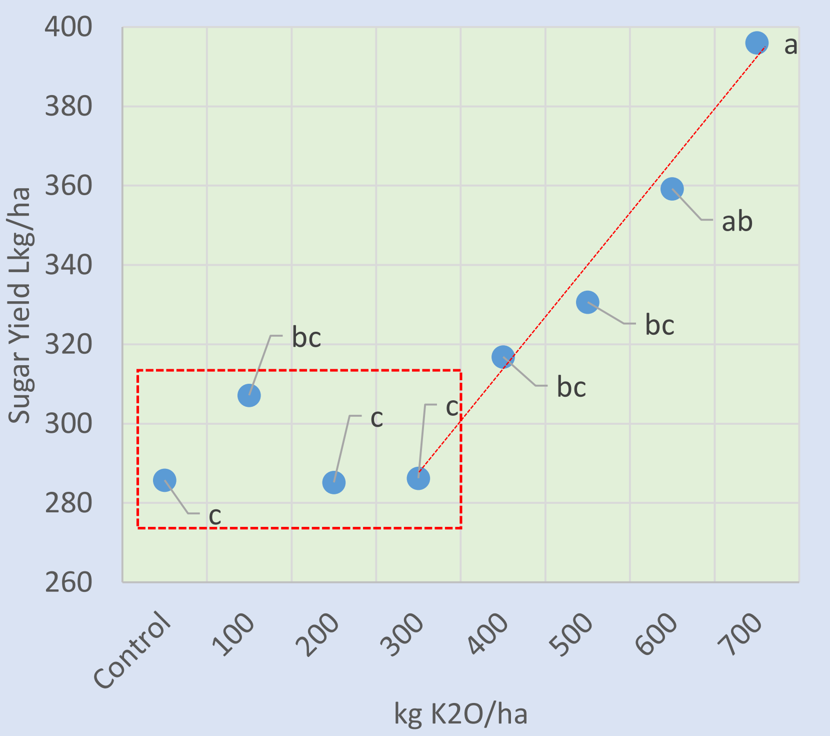
Nitrogen Field Trial



Phosphorus Field Trial



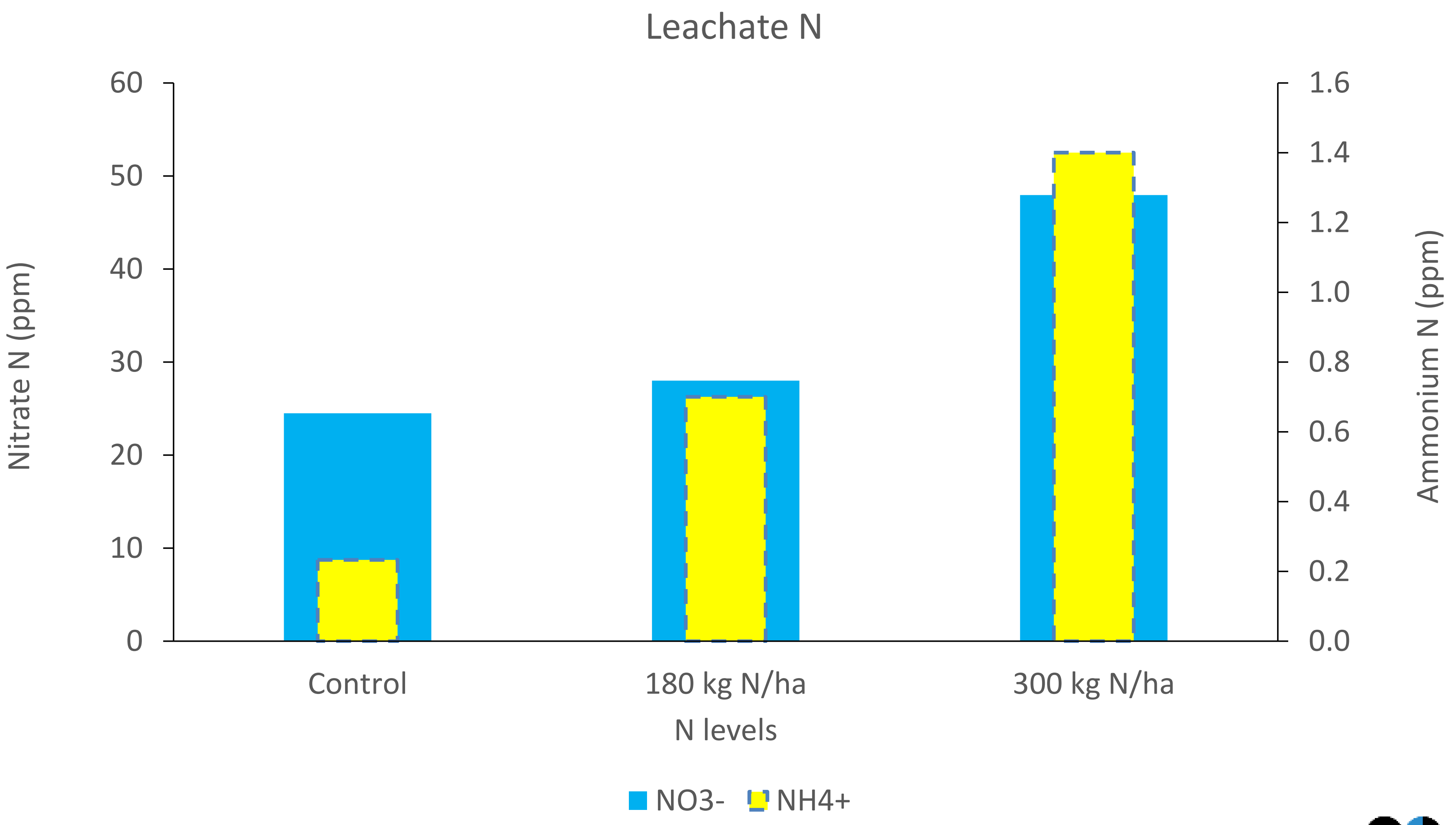
Potassium Field Trial



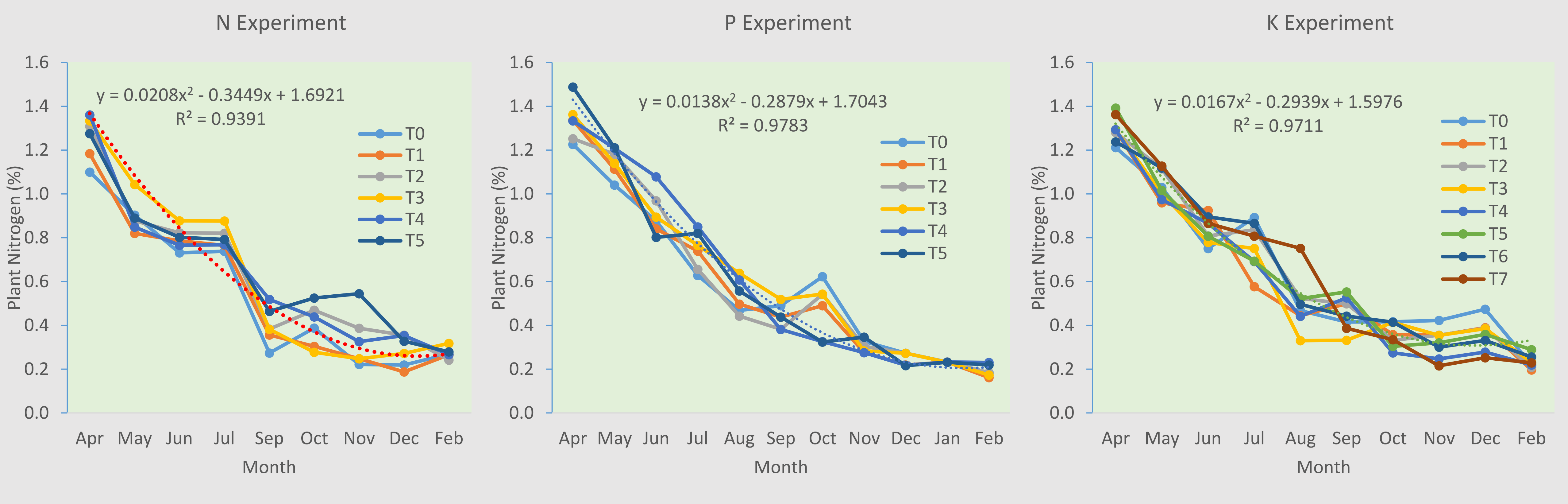
Means with common letter(s) within the same column and treatment group are not significantly different at 5% level of significance based on LSD.


Accomplishments
(Nutrient Dynamics)

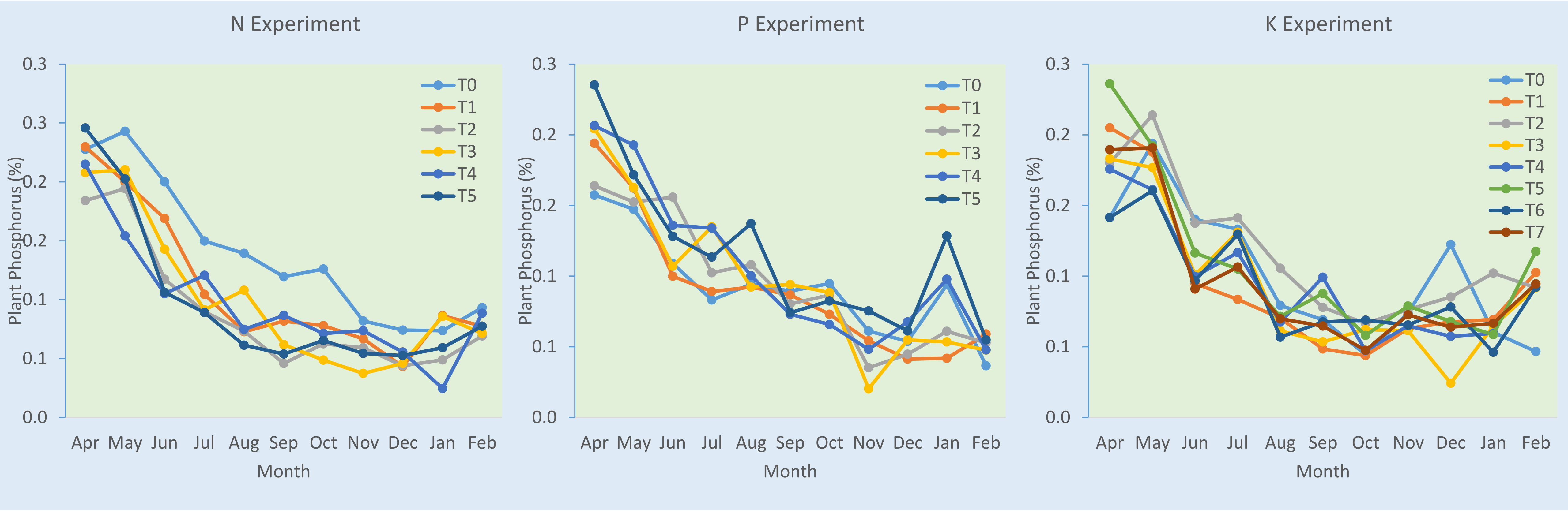
Leaching of N



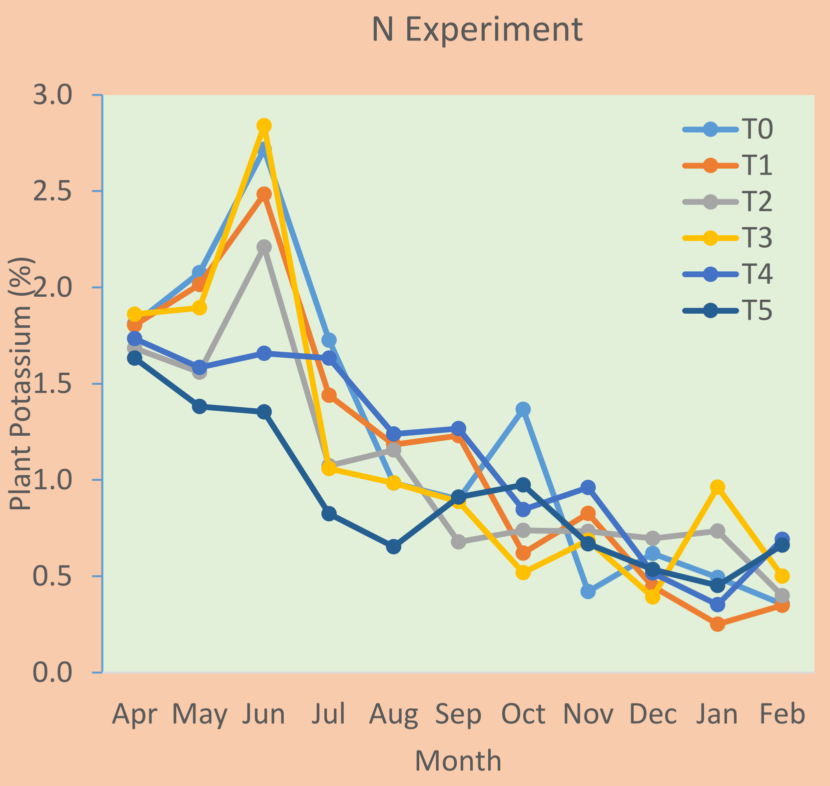
Plant Nitrogen Dynamics

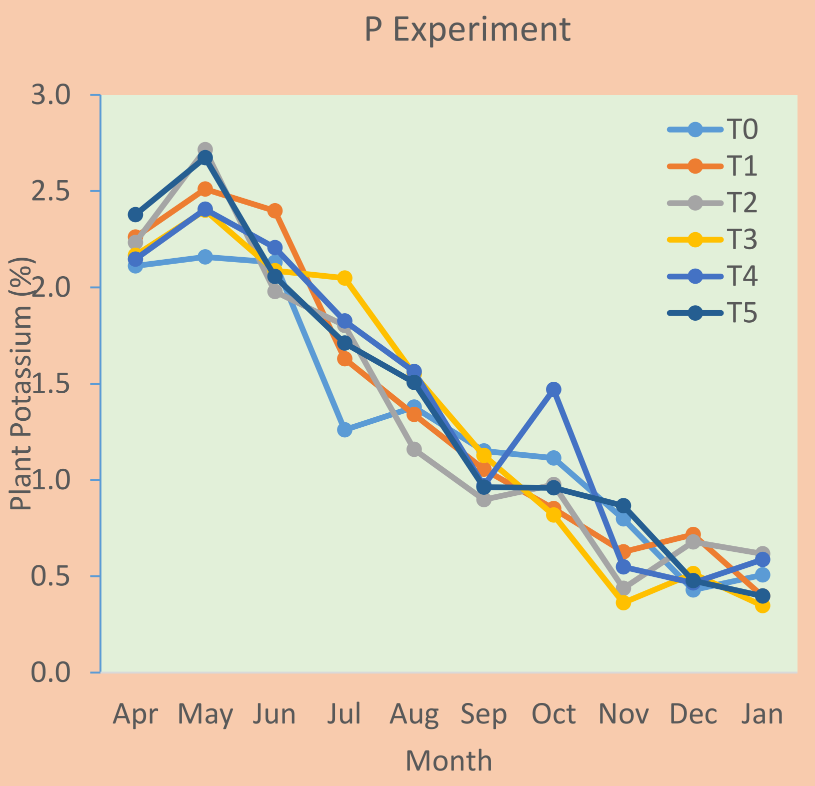


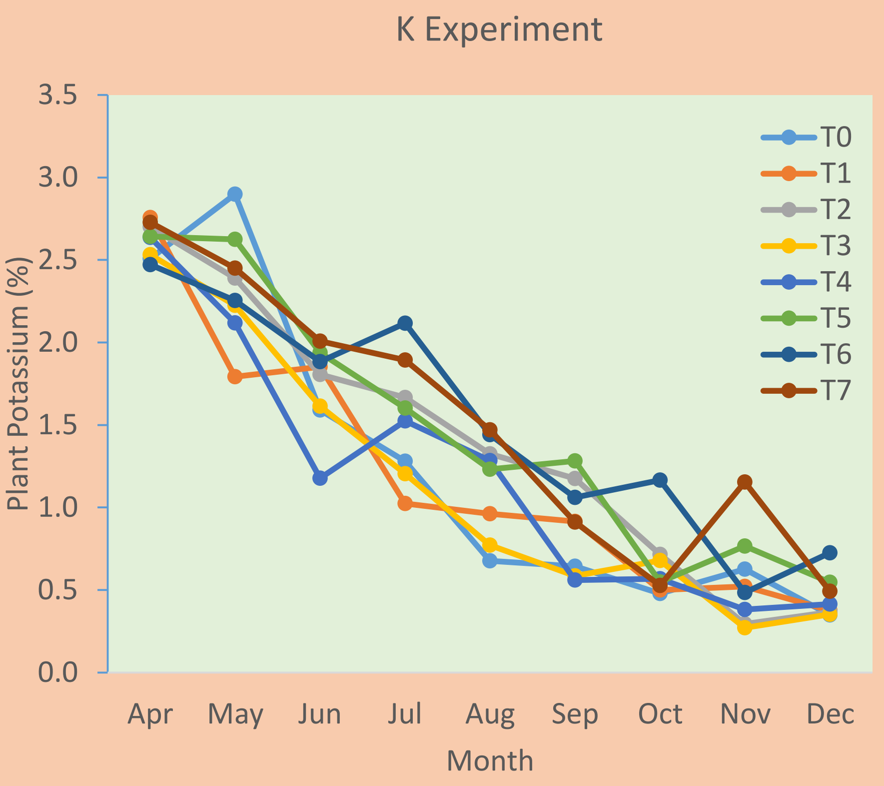
Plant Phosphorus Dynamics



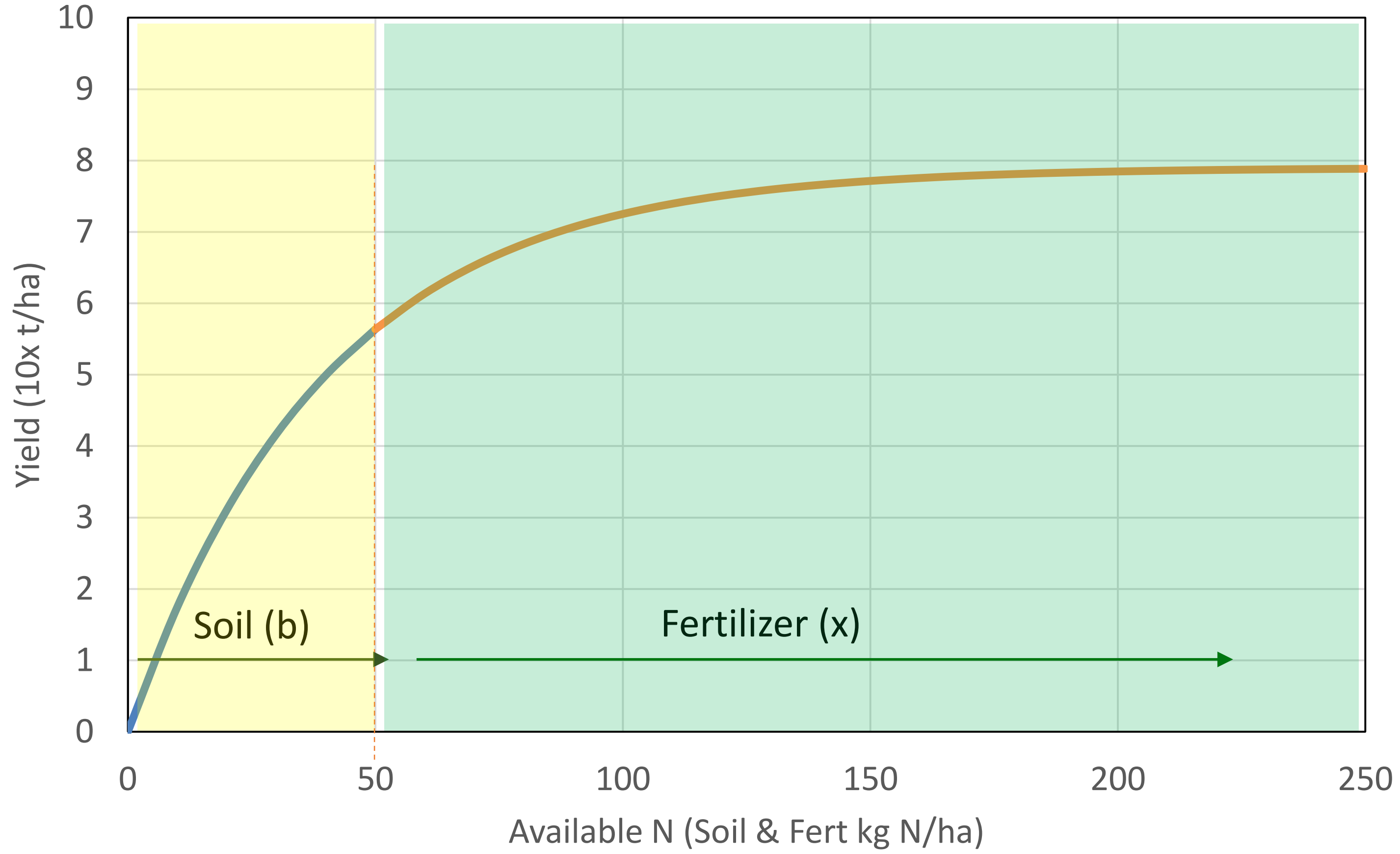
Plant Potassium Dynamics







Crop Response Model



Mitscherlich equation for crop response

$$y = A[1 - \exp(-c_i x_i)]$$

y = yield obtained for a given quantity of the nutrient x
A = maximum yield attainable
Ci = proportionality constant
Xi = Nutrient

Mitscherlich (1909) **The law of the minimum and the law of diminishing soil productivity**

Soil Test, Native Nutrients and Fertilizers

Mitscherlich equation for crop response

$$y = A[1 - \exp(-c_i x_i)]$$

Xi = Native available nutrient (ba) + Applied nutrient (xa)

Soil test values and control plots

Efficiency coefficients **(isotopic tracer)**

Amount applied

Lesson learnt:

Challenges/issues faced during the field work?

- ✓ Occurrence of strong typhoons which brought heavy rainfalls causing some rotting of cane stalks.
- ✓ Sampling in sugarcane field is very difficult especially during maturity or sugar accumulation period.
- ✓ The infestation of rats and termites in the area cause damage to the installed data logger and soil moisture sensors.
- ✓ Collaborating agency undergone a rationalization plan for their employees hence, project staffs involved have been replaced by new ones. Orientation has been conducted for them on the overview and goals of the RAS project. The new research personnel need an intensive training on the nuclear analytical techniques and methodologies used in the project.

What was new?

The use of ^{15}N tracer techniques in attempt to refine and update the fertilizer requirement in lahar laden sugarcane production areas is the first of its kind in the Philippines.

What was positive?

- ✓ The Soil Science and Plant Nutrition Laboratory has acquired a new Isotope Ratio Mass Spectrometer from the local funding agency to support the various projects under the IAEA.
- ✓ Collaborators and stakeholders welcomed the nuclear and isotope techniques as one of the best method for assessing the nutrient and crop water requirement, hence local funding agency were very supportive for the project.

How to move forward?

- ✓ The output of the project particularly on the refinement of fertilizer recommendation is very important as this can be used and applied to other sugarcane growing regions with similar climatic, pedological, and ecological conditions and where site specific information on fertilizer requirements is limited.
- ✓ Continue the analysis of all data before the project ends

Future work plan:

- ✓ Continue the field trials for the next cropping season (ratoon cropping) and for putative mutants/mutants screened
- ✓ Generate sugarcane production guide
- ✓ Validate and dissemination of results to stakeholders.

Establishment and Development of local and regional networking:

To make more awareness of the best use of marginal land for sugarcane crop dissemination of technical information to researchers/extension workers/farm consultants and end users (farmers).


Thank you!