# Tropical Legumes for Sustained Cropping on Marginal Soils

Tim Motis

A summary of ECHO research in South Africa (2010-2015)

# Importance of legumes

Their relevance to small-scale farmers

# What is a legume?

- Any plant belonging to the family, fabaceae (leguminosae)

- A few characteristics:
  - Pods of most legumes split along 2 sides/seams.
  - Roots host bacteria (rhizobia) within nodules. These bacteria “fix”/convert nitrogen from the air into nitrogen that plants can use.

- Some legumes do well in temperate climates; our focus was on those that thrive in tropical areas.

# What do legumes provide to farmers?

- Soil nitrogen, an essential plant nutrient that is commonly lacking
- Ground cover (mulch)/soil organic matter
- A low-cost source of protein for human and animal consumption
- Weed suppression

# What farmer constraints can be addressed with legumes?

- Marginal soil conditions
- Pressure to produce food on the same land each year
- Challenges in replacing nutrients
  - Low organic reserves of fertility
  - Limited manure or mineral fertilizer
  - Crop yield decline on depleted soils

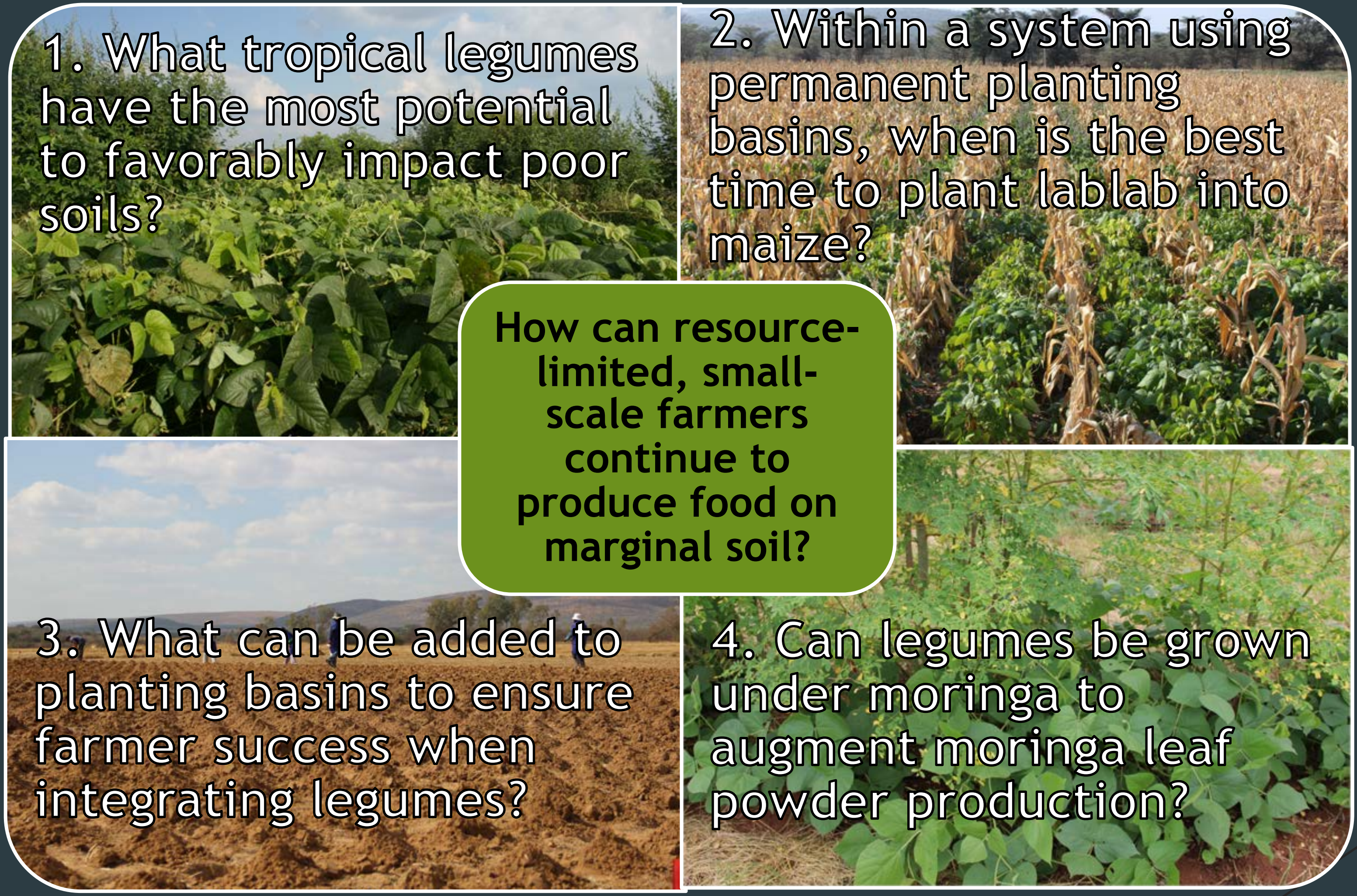
# About ECHO research in South Africa

Context and purpose

- Funding and logistical support provided by the Howard G. Buffett Foundation
- Time frame: 5 years (2010 to 2015)
- Location: Ukulima Farm in Limpopo Province

# Location of ECHO research in RSA

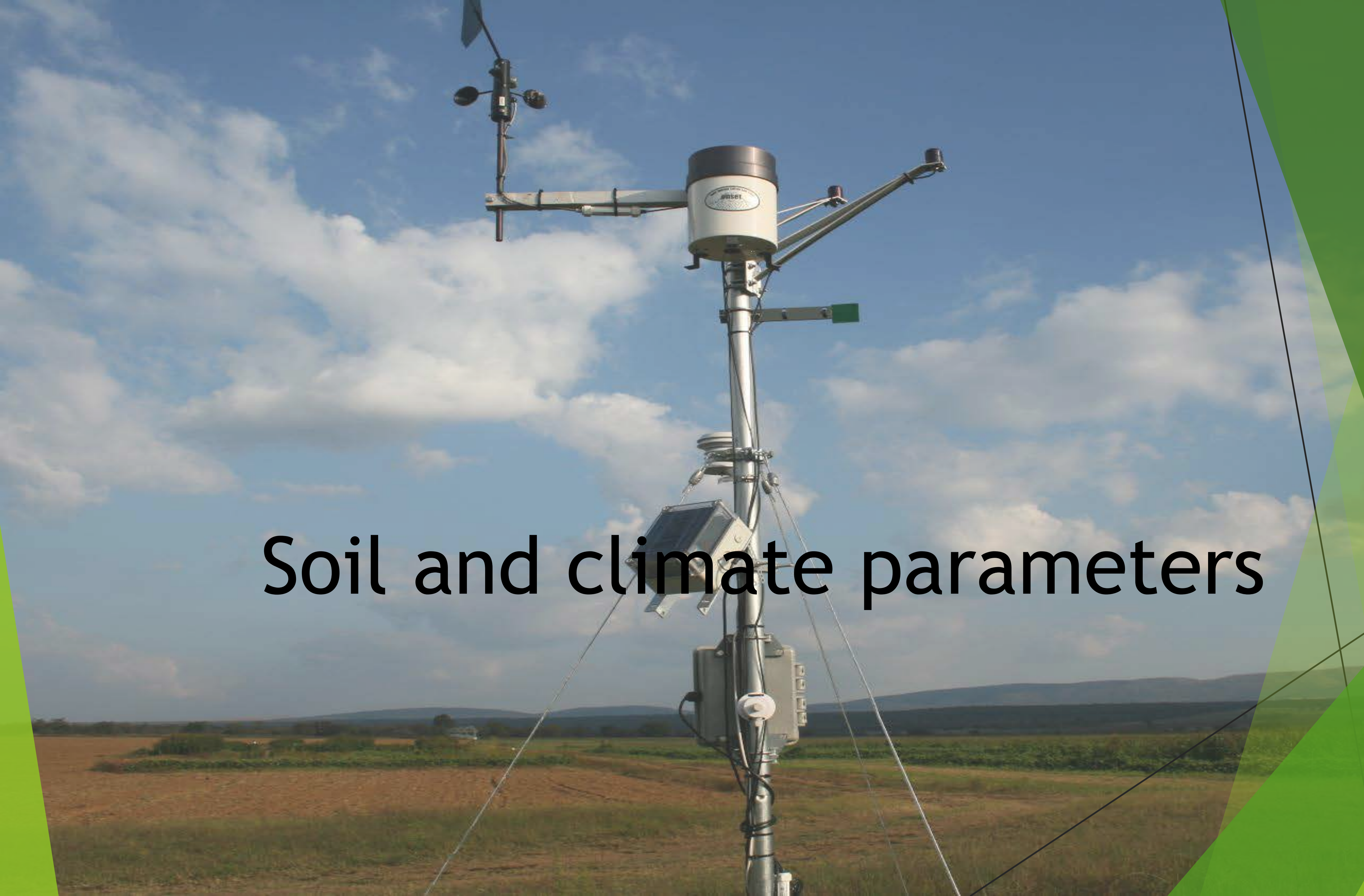
# Purpose: questions addressed



# Presentation plan

- Describe soil and climatic factors
- For each question addressed by the research, present key take-a-ways and supporting data
- Recap lessons learned, with thoughts on how to apply them elsewhere

# Soil and climate parameters



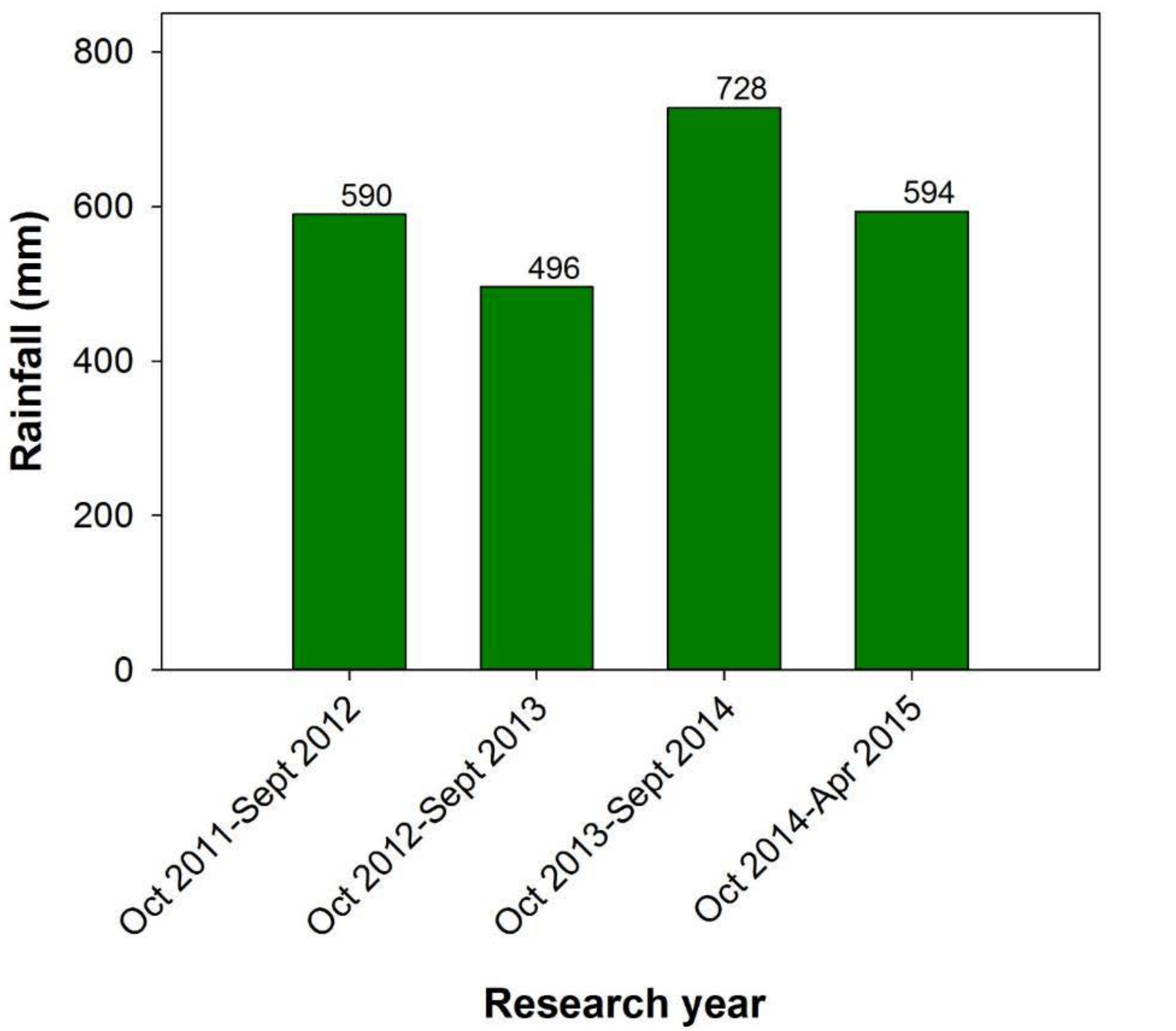
# Baseline soil conditions

- Texture:
  - 89% sand
  - 7% silt
  - 4% clay

| | pH | OM | $NO_3$- | P | K |
|---|---|---|---|---|---|
| Actual | 5.7 | 0.7% | 4 ppm | 26 ppm | 63 ppm |
| Desired level | 6.5-7.0 | 2% | 20 ppm | 20-39 ppm | 117 ppm |

# Climate: rainfall

Rainfall amounts were consistent with semi-arid conditions



# Seasonal air temperature (˚C)

| Time period | Minimum | Maximum |
| --- | --- | --- |
| Growing season (Sept-May) | 6 to 13 | 32 to 38 |
| Winter (June-August) | As low as -7 | 22 to 32 |

# What tropical legumes have the most potential to favorably impact poor soils?

Research question 1

# Ground prep for a screening trial


| # | Legume species/combinations |
|---|---|
| 1 | Control- bare ground |
| 2 | Control- natural/weedy fallow |
| 3 | Pigeon pea (*Cajanus cajan*) |
| 4 | Pigeon pea + cowpea (*Vigna unguiculata*) |
| 5 | Pigeon pea + lablab 'Highworth' (*Lablab purpureus*) |
| 6 | Jack bean (*Canivalia ensiformis*) |
| 7 | Sunnhemp (*Crotalaria juncea* 'IAC-1') |
| 8 | Lablab 'Tahoua' + cowpea |
| 9 | Lablab 'Highworth' |
| 10 | Horsegram (*Macrotyloma uniflorum*) |
| 11 | Velvet bean (*Mucuna pruriens* 'Bush') |
| 12 | Velvet bean (*Mucuna pruriens* 'Vining') |
| 13 | Tephrosia (*Tephrosia vogelii*) |
| 14 | Cowpea (*Vigna unguiculata*) |

# Legumes were direct seeded (50 X 50 cm)

# What the trial looked like when established

# Key take-a-way

Legumes thrived in dry sandy soil, contributing significant amounts of plant-based mulch.

# Top-performing legumes

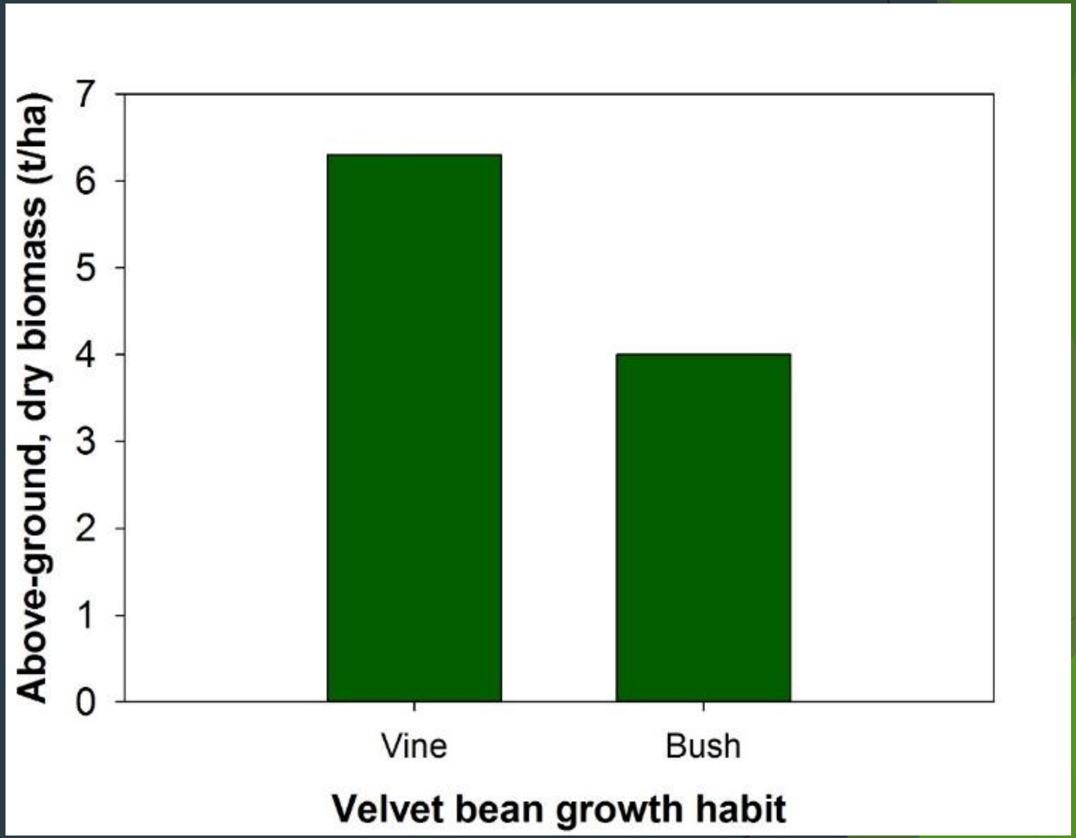
- Lablab (*Lablab purpureus*)
- Cowpea (*Vigna unguiculata*)
- Horsegram (*Macrotyloma uniflorum*)
- Velvet bean (*Mucuna pruriens*)
- Pigeon pea (*Cajanus cajan*)

# Lablab ‘Highworth’: 8 to 13 t/ha above-ground dry matter

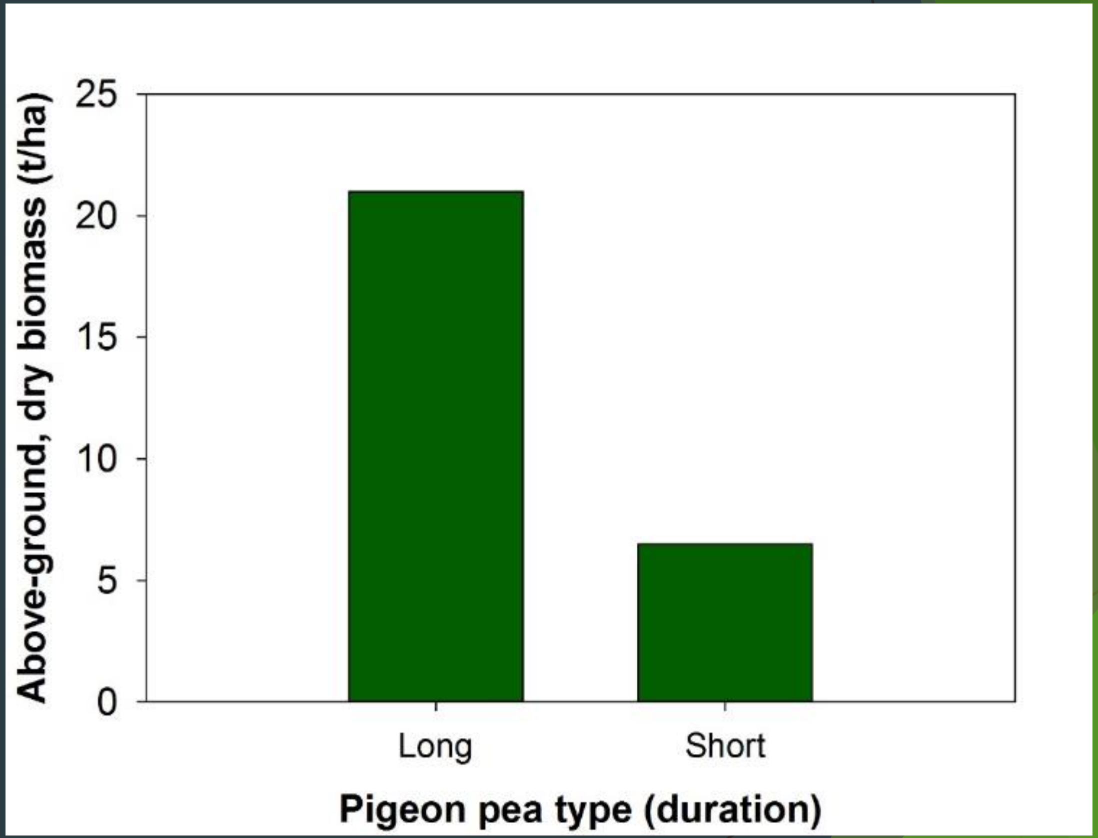
# Cowpea: 4 to 6 t/ha dry matter

# Horsegram: 5 to 9 t/ha dry matter

# Velvet bean---vining (top) and bush(bottom)



# Pigeon pea: long (top) vs short (bottom) duration



# *Tephrosia vogelii*: 10 t/ha dry matter

# Residue of season-1 legumes, at the beginning of season 2

# Residue going into season 2- lablab (left) and horsegram (right)

Lablab: 11.6 t/ha dry matter

Horsegram: 8.2 t/ha dry matter

# Residue going into season 2- tropical (left) vs bush (right) velvet bean

**Vining velvet bean: 8.0 t/ha dry matter**

**Bush velvet bean: 4.1 t/ha dry matter**

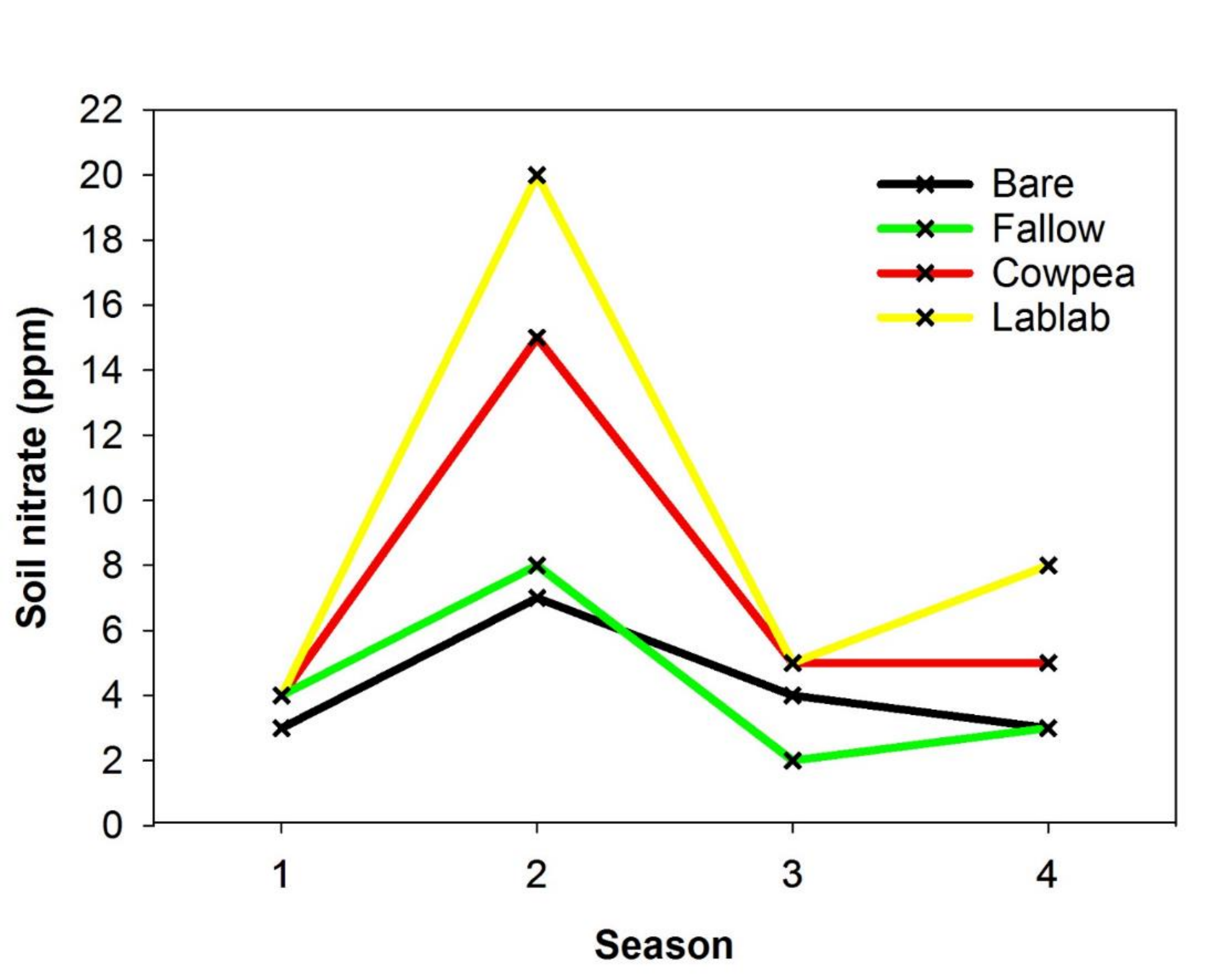
# Key take-a-way

Legume biomass served as a better source of nitrogen than weedy fallow biomass.

# Legumes with more nitrogen than weeds in natural fallow plots

| Legume | Concentration of N in plant tissue (%) | Accumulation of N in above-ground biomass (kg of N per hectare) |
|---|---|---|
| Weedy fallow | 2.1 | 178 |
| Lablab | 3.9 | 318 |
| Lablab + cowpea | 4.0 | 279 |
| Velvet bean (vining) | 3.2 | 188 |
| Pigeon pea | 2.8 | 556 |

# Soil nitrate from the beginning of season 1 to the end of season 4

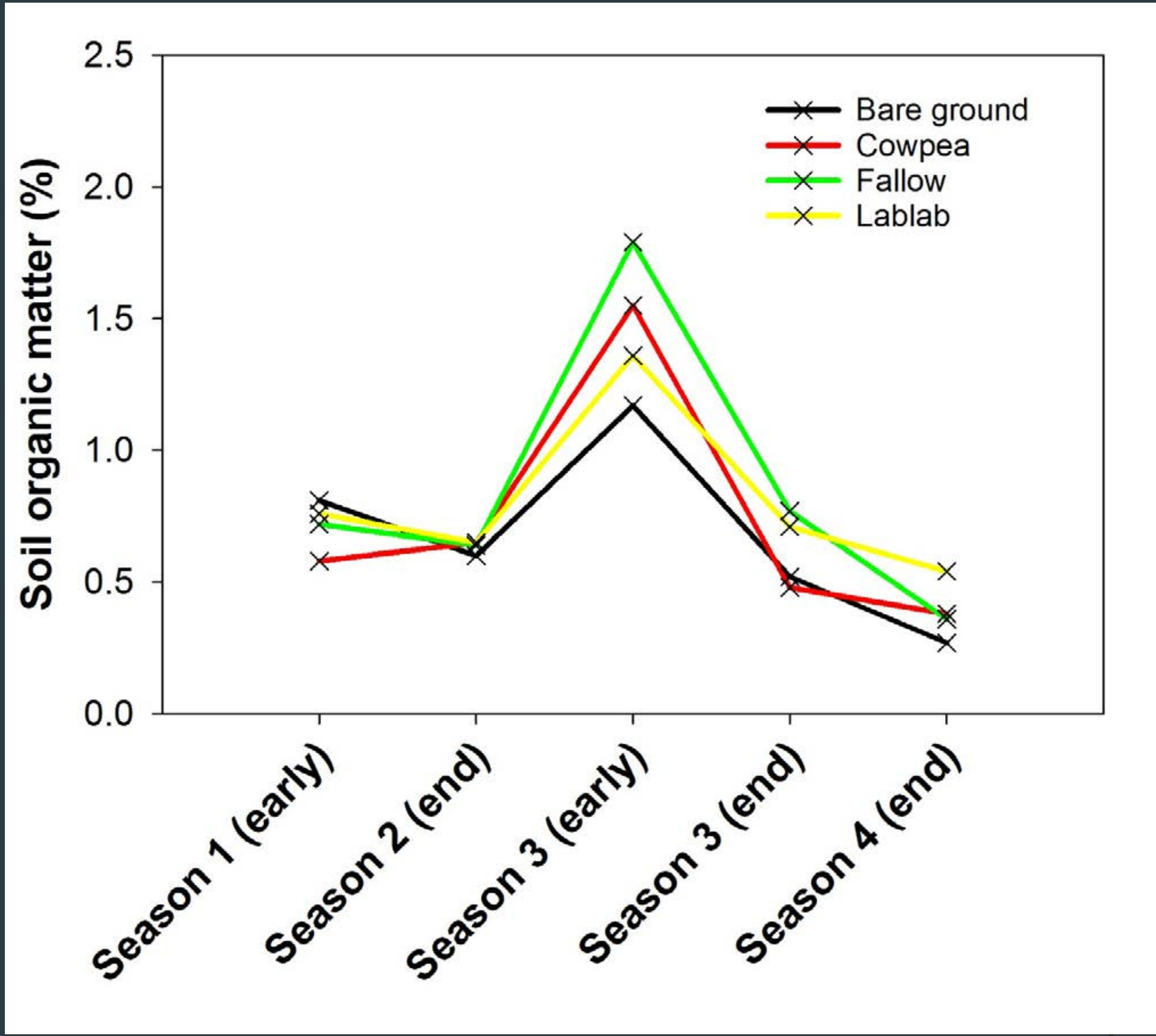


# Root colonization of N-fixing bacteria

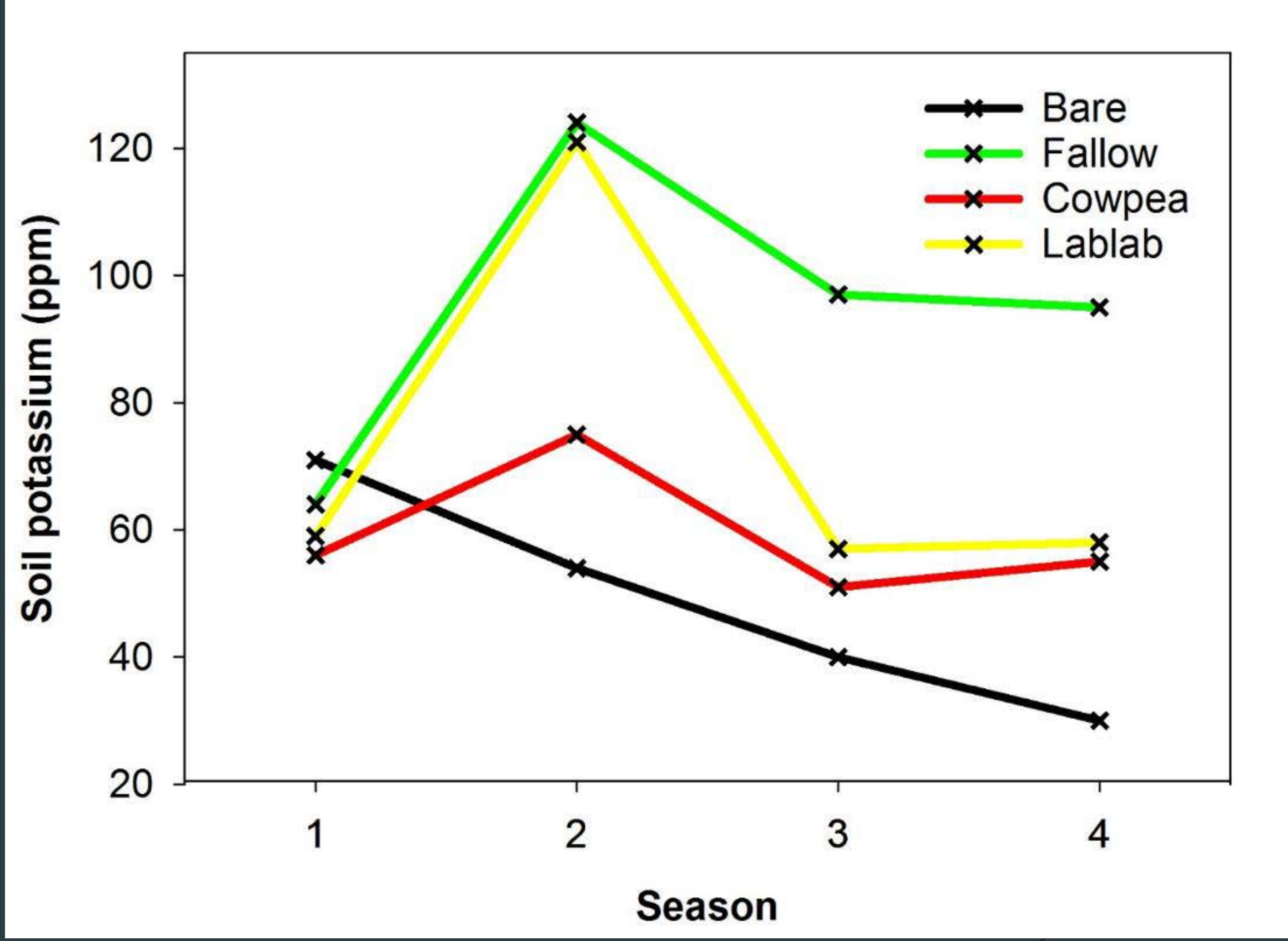
# Key take-a-way

Leaving legume and fallow residue on the ground helped maintain soil organic matter and nutrients.

# Soil organic matter from the beginning of season 1 to the end of season 4



# Soil potassium from the beginning of season 1 to the end of season 4



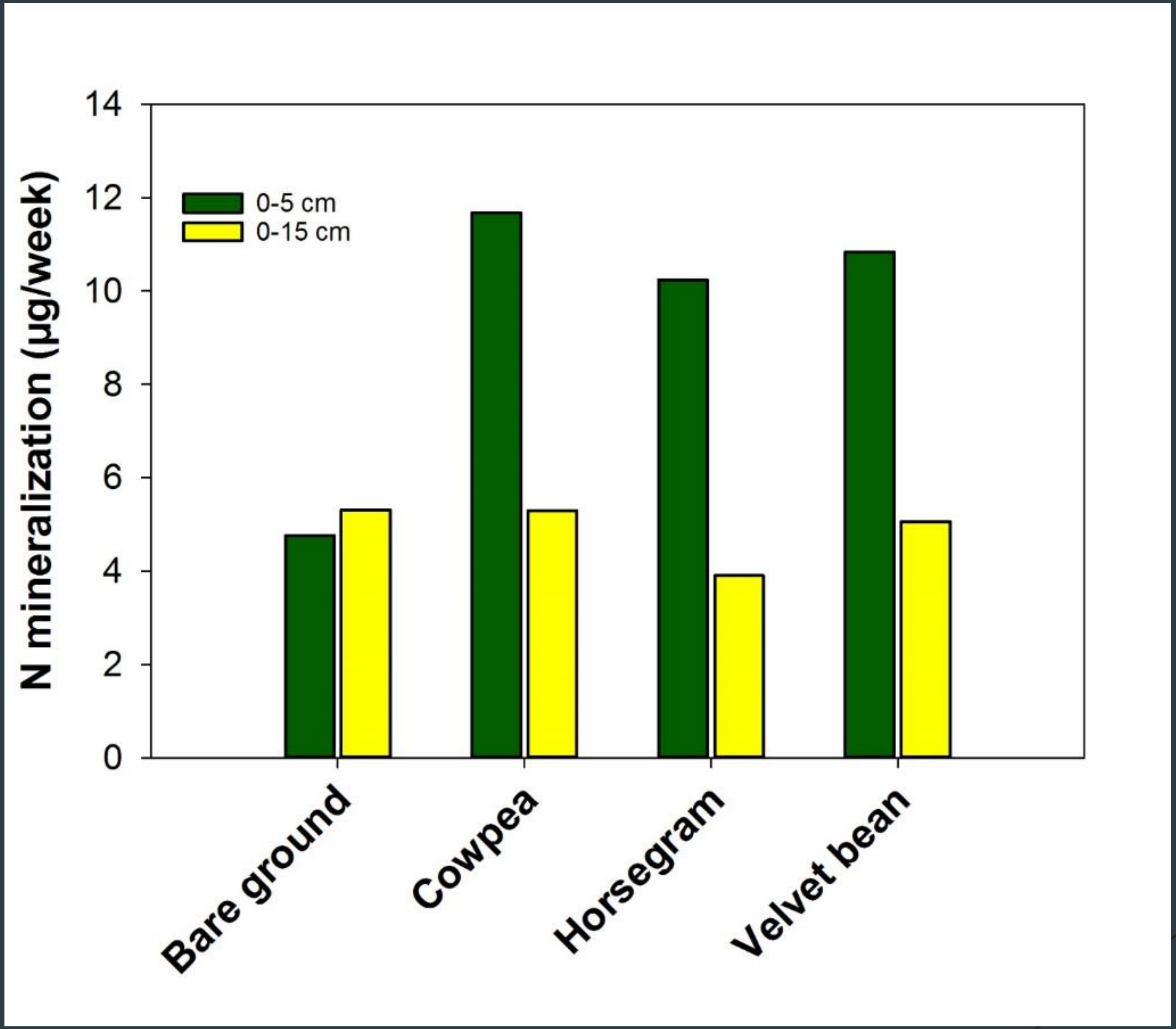
## Change in pH and macro/secondary nutrient values from the beginning of season 1 to the beginning of season 3.

| | pH | $NO_3^-$ | P | K | Mg | Ca | S |
|---|---|---|---|---|---|---|---|
| Year | Bare ground | | | | | | |
| 2011 (baseline) | 5.75 | 3 | 26 | 71 | 49 | 326 | 8 |
| 2013 | 5.28 | 3 | 31 | 42 | 35 | 246 | 10 |
| P value | 0.0050 | 0.8801 | 0.1041 | 0.0808 | 0.0031 | 0.0015 | 0.6611 |
| | | | | | | | |
| Year | Legumes (average of cowpea, lablab and velvet bean) | | | | | | |
| 2011 (baseline) | 5.74 | 4 | 26 | 63 | 48 | 295 | 4 |
| 2013 | 5.78 | 11 | 33 | 83 | 62 | 292 | 9 |
| P value | 0.6207 | 0.0003 | 0.0005 | 0.0039 | <0.0001 | 0.7831 | 0.0003 |

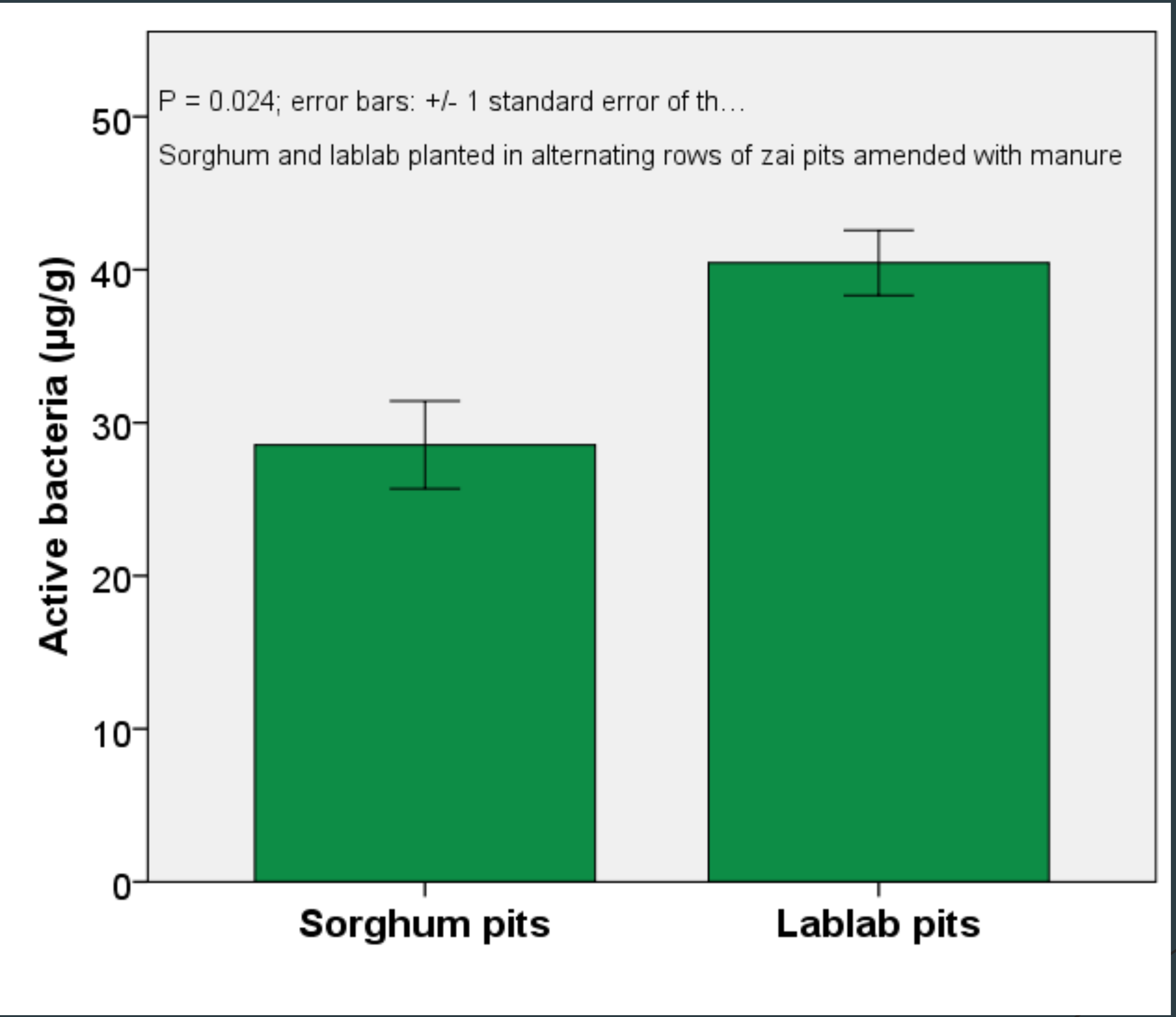
# Key take-a-way

**Legume residues, left at the soil surface, favorably influenced nitrogen cycling by microbial life.**

# Soil N mineralization at 2 soil depths



# Active bacteria in sorghum versus legume zai pits



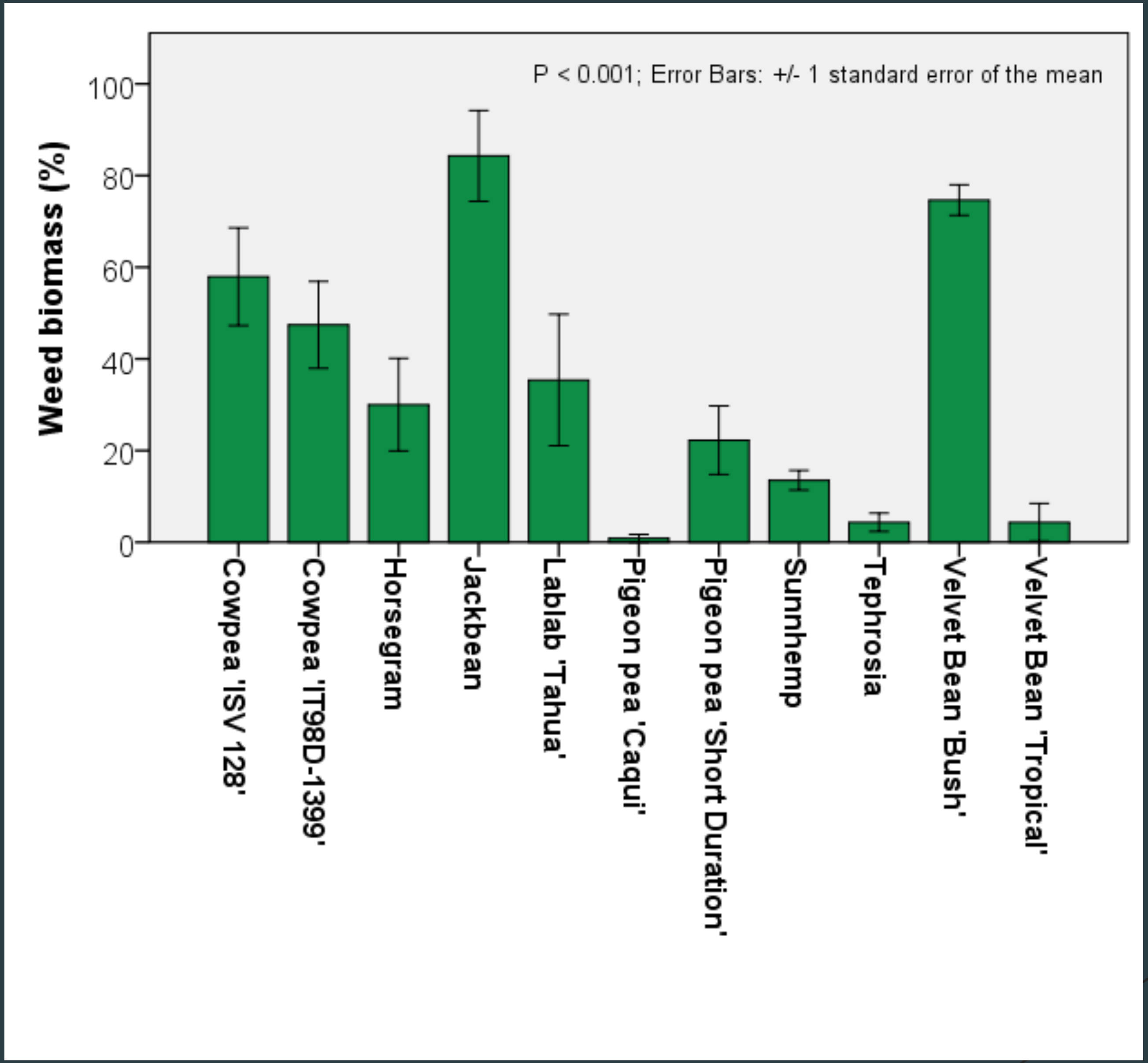
# Key take-a-way

Less weed growth under legumes with dense leaf canopies.

# 1 meter square sampling tool

Above-ground legume and weed biomass cut at ground level and then dried/weighed to get legume and weed dry matter.

# Percentage of biomass as weeds



# When is the best time to plant lablab into maize?

Research question 2

# Focused on lablab/cowpea based on previously-conducted intercropping trials.




# A timing trial established, using permanent planting stations.

This is hard work! By digging a few hours a day during the dry season, the field will be ready when the rain arrives.


I’m tired!!

# Treatments and inputs:

- Lablab planted at 0 (same time as maize), 2, 4, 8 and "12" (never planted) weeks after maize; with and without cowpea.
- All planting basins received 500 ml of cattle manure. Maize basins also micro-dosed with NPK fertilizer.
- Legumes (lablab/cowpea) planted in alternating rows with maize.

# ECHO maize/lablab intercropping method

- Planting multiple crops in same field each year
- Rotate rows: Do not plant same crops in same rows each year
- Spacing: 50 cm between rows and 60 cm within row

Maize – M

Cowpea – C

Lablab - L

**Year 1**

| | | | |
|---|---|---|---|
| M | L | M | L |
| | C | | C |
| M | L | M | L |
| | C | | C |
| M | L | M | L |
| | C | | C |
| M | L | M | L |
| | C | | C |
| M | L | M | L |

**Year 2**

| | | | |
|---|---|---|---|
| L | M | L | M |
| C | | C | |
| L | M | L | M |
| C | | C | |
| L | M | L | M |
| C | | C | |
| L | M | L | M |
| C | | C | |
| L | M | L | M |

# Key take-a-way

Lablab could be planted the same time as maize without reducing maize growth/yield.

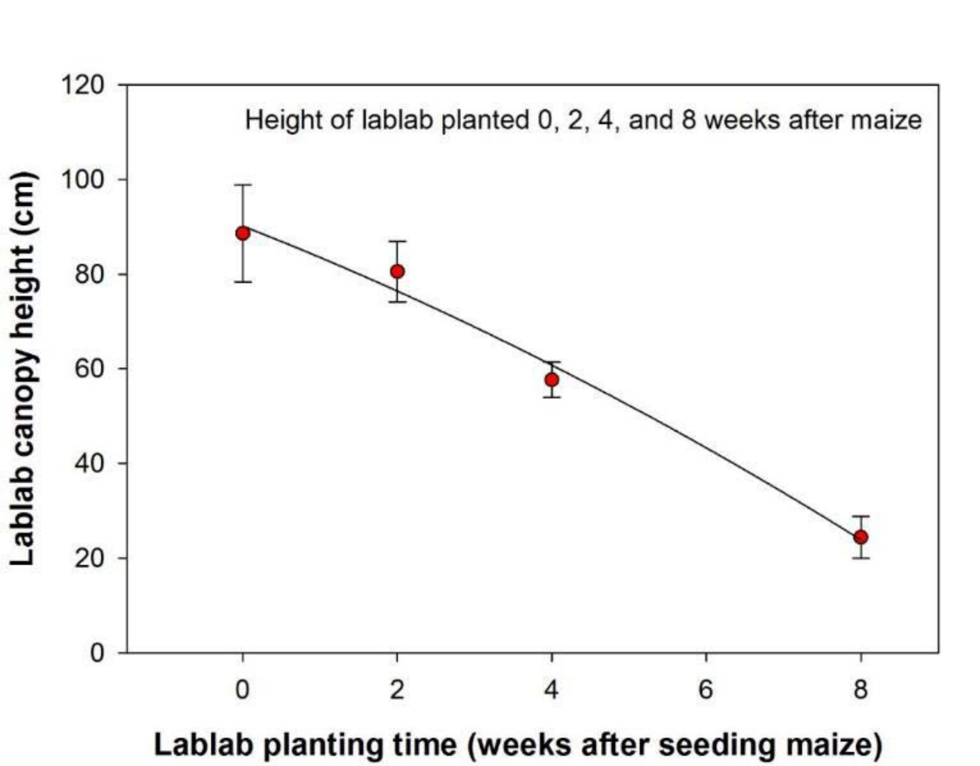
# Planting lablab at the same time as maize had no adverse effect on:

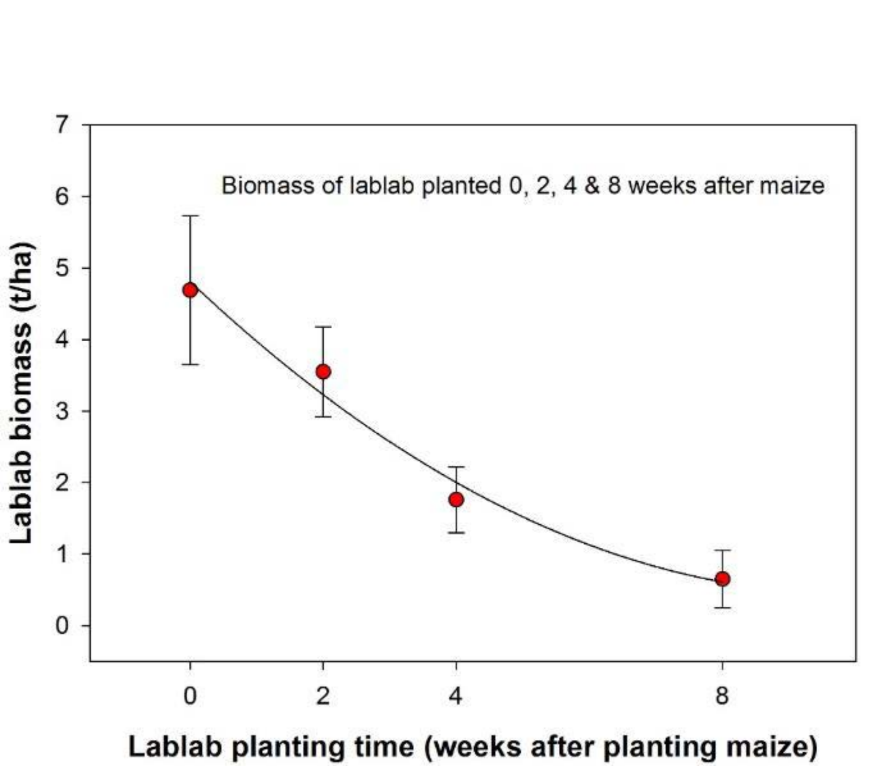
- Maize growth: up to 2.3 m
- Cowpea growth: 35-40 cm in height; 2-3 t/ha biomass
- Maize and cowpea grain yield
  - Maize: up to 2.8 t/ha
  - Cowpea: up to 650 kg/ha in season
  - Lablab: pods failed to mature before winter dry season

# Key take-a-way

Lablab, intercropped with maize, grew best when planted early.

# Final height and biomass of lablab



# Key take-a-way

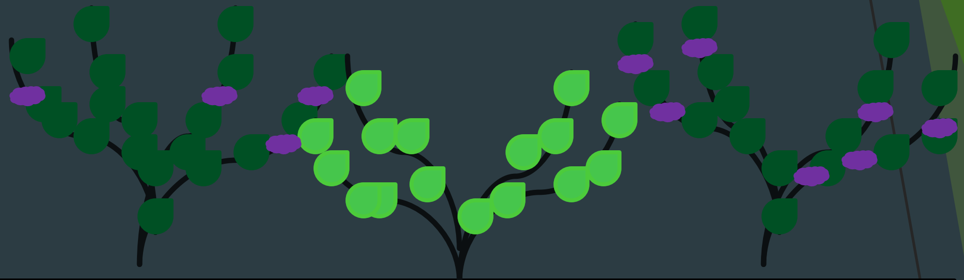
Legume combinations provided early- and late-season food/mulch.

Week 4 Cowpea Lablab

Initial cowpea growth is faster than lablab

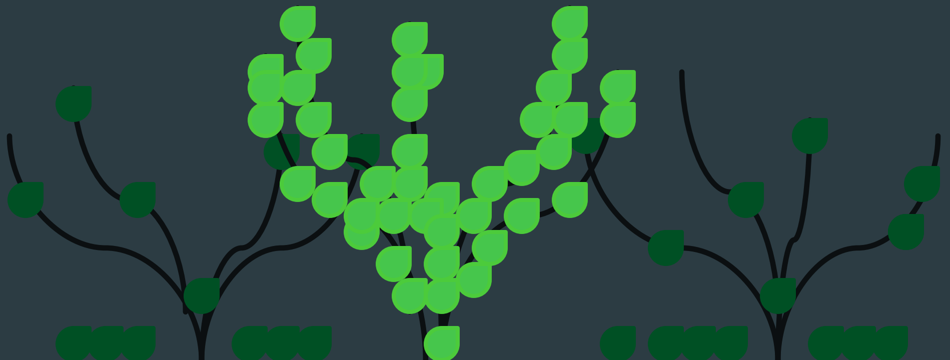
Week 8

Cowpea flowering and producing pods, while lablab growth rate is increasing



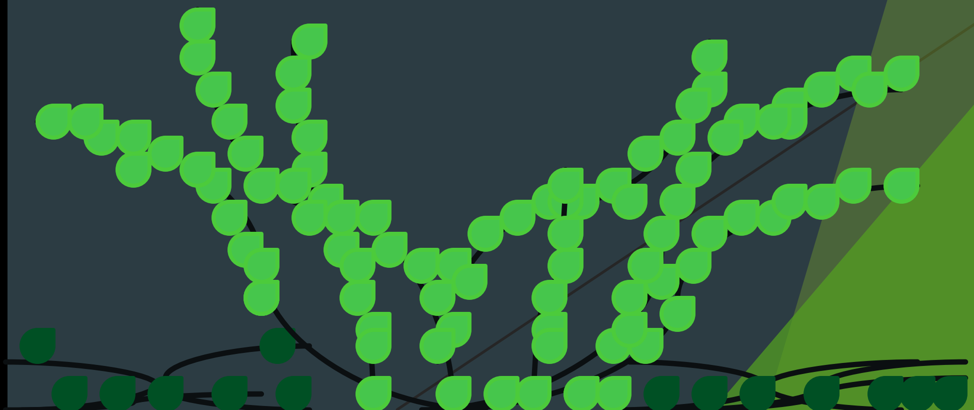
Week 12

Cowpea is in decline just as lablab is growing rapidly



Week 16

Cowpea is decomposing as lablab takes over



# Harvestable cowpea by maize tasseling time

# Key take-a-way

The presence of lablab after maize harvest represents dry-season options for ground coverage or livestock feed.

# End-of-season biomass

Easy to manage, but few options for dry-season mulch or fodder

Harvest/management more difficult, but more food options.

# What can be added to planting basins to ensure farmer success when integrating legumes?

Research question 3

# Amendments trialed in combination with cowpea/lablab intercropping

| Amendments placed in planting basins. | | |
|---|---|---|
| No. | Amendment | Amount/station |
| 1 | None | N/A |
| 2 | Unimproved cow manure | 500 ml |
| 3 | Composted cow manure | 500 ml |
| 4 | Mineral fertilizer | 10.8 g (maize only) |
| 5 | Composted cow manure<br>Mineral fertilizer | 500 ml<br>10.8 g (maize only) |
| 6 | Biochar/composted cow manure<br>Mineral fertilizer | 500 ml<br>10.8 g (maize only) |

# Composted manure + biochar + NPK

Mineral fertilizer analysis: 12% N; 9% P; 12% K
Mineral fertilizer supplied 22 kg/ha of nitrogen

# Making biochar


T-lud method

Heated to 500 °C

# Biochar---final product

**Maize biochar analysis**

| pH | N (%) | P (%) | K (%) |
|---|---|---|---|
| 10.5 | 0.95 | 0.18 | 1.98 |

# Composted cattle manure

- Ratio: 4 dry/brown:2 manure:4 green (buckets)
- Dry/brown materials added: *Terminalia sericea* branches, cowpea pods, and hay/straw
- Greens: Terminalia leaves and khaki weed (*Tagetes minuta*)
- Water: 880 L (50% moisture)

1.5 wide X 1.5 deep X 1.3 high (m)

# Key take-a-way

Modest fertility inputs significantly increased the yield of maize grown with legumes.

# Observable differences soon after planting

# Treatment effects 5 weeks after seeding maize and legumes

No amendment

Compost+NPK

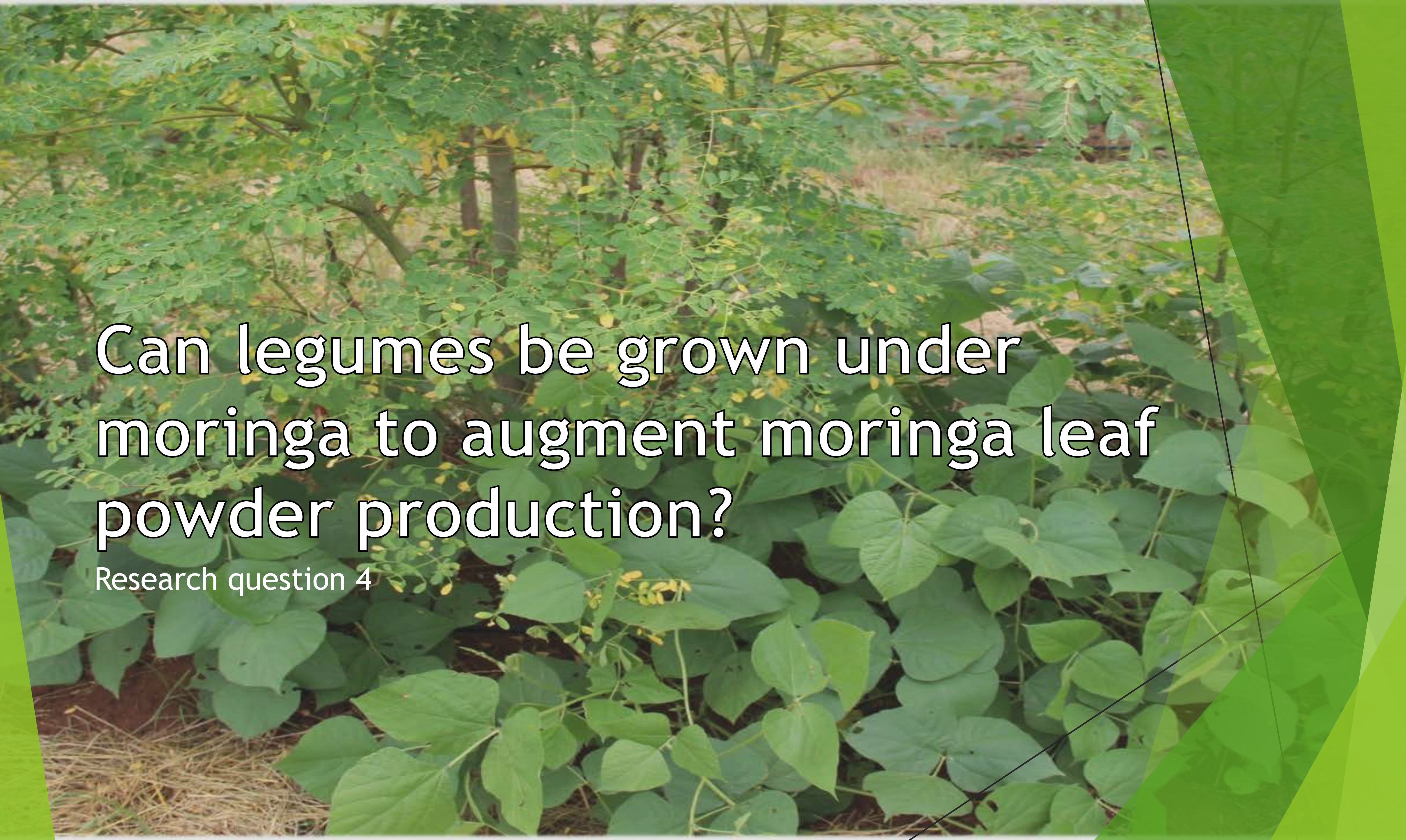
# Maize grain yield response to fertility inputs added to basins

| Soil amendment + cowpea/lablab | Grain yield (t/ha) | Yield increase in comparison to no amendment |
|---|---|---|
| None | 1.2 | --- |
| Cattle manure | 1.6 | 33% |
| Composted cattle manure (CCM) | 1.8 | 50% |
| NPK | 2.2 | 87% |
| CCM + NPK | 2.5 | 117% |
| CCM + NPK + biochar | 2.4 | 109% |

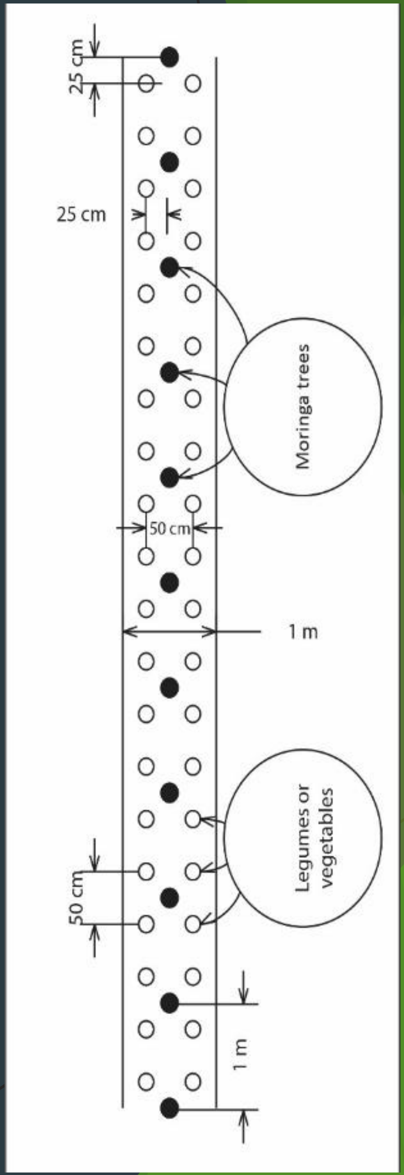
Average yield for sub Saharan Africa = 1.4 to 1.8 t/ha

# Can legumes be grown under moringa to augment moringa leaf powder production?

Research question 4



# Moringa/legume intercropping pattern

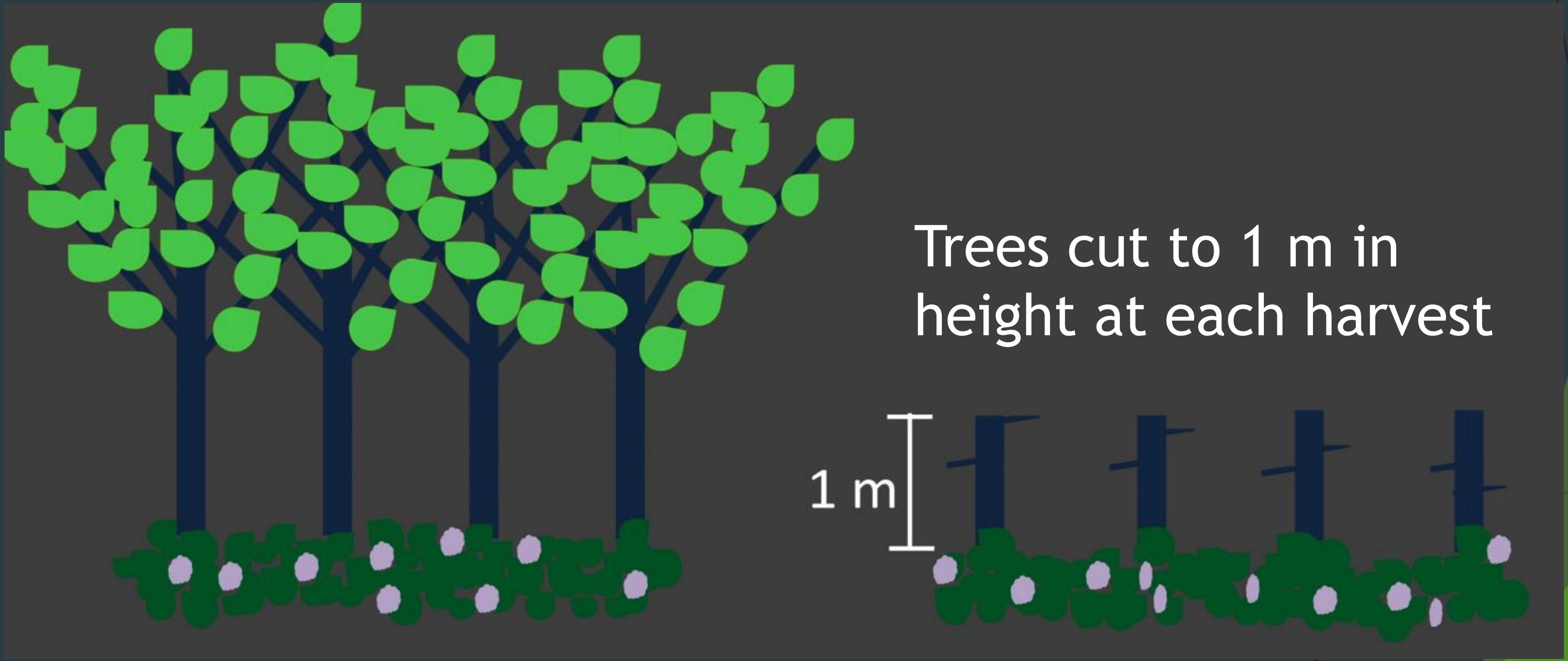


# Moringa trial planting sequence

- 2011-12: Moringa trees established
- 2012-13: Cowpea, jack bean, lablab, pigeon pea
- 2013-14: Okra and kale
- 2014-15: Cowpea, jack bean, lablab, pigeon pea

# Inputs and harvesting details

- Chicken manure applied at base of trees @ 5 tons/ha (3 times/season)
- Moringa leaves harvested twice during rainy season



# Key take-a-way

Mulch increased moringa tolerance to short-duration freezes during the winter dry season.

# Trees heavily mulched with straw during winter seasons; the straw was removed each spring

# Key take-a-way

Legumes grew well under moringa, contributing added food options.

# Legume Growth

Tropical legumes thrived under the moringa canopy, covering the ground beneath the trees.



# Moringa/legumes prior to harvest

# Moringa harvest

# Moringa leaf drying

# Moringa trees just after harvest

# Outputs (per ha)

- Moringa powder: 250 kg by 2$^{nd}$ season

  **Supplies 136 people each year with a reasonable daily dose of 1 tablespoon (5 g) of moringa powder**

- Jack bean & lablab: > 4 t dry biomass and 500 kg beans
- Cowpea:  1 t dry biomass and > 200 kg beans

# Application

Some closing thoughts

# Legume evaluation

- Grow promising legumes in small plots to see what works best in your area. Involve farmers as much as possible.

- Evaluate the legumes under the same conditions that farmers face.

# Intercropping strategy\ legume selection

- Select a legume or legume combination that produces enough residue to favorably impact the soil.
- Match low-growing (e.g., cowpea) and/or slow-to-establish (e.g., lablab or pigeon pea) legumes with tall cereal crops.
- Select a legume or combination of legumes that extends the time over which the soil is covered and that food is produced.
  - Consider cowpea for early-season ground coverage and food production
  - Consider lablab or pigeon pea for post-maize ground cover and food production

# Intercropping strategy\ legume planting time

- Plant all crops at the same time to:
  - Simplify management
  - Take full advantage of short rainy seasons

- Delay planting of the legume if the farmer is growing a short-statured grain (e.g., some millet varieties), or if there is a high chance that the cereal crop will be stunted due to lack of fertility inputs or rainfall.

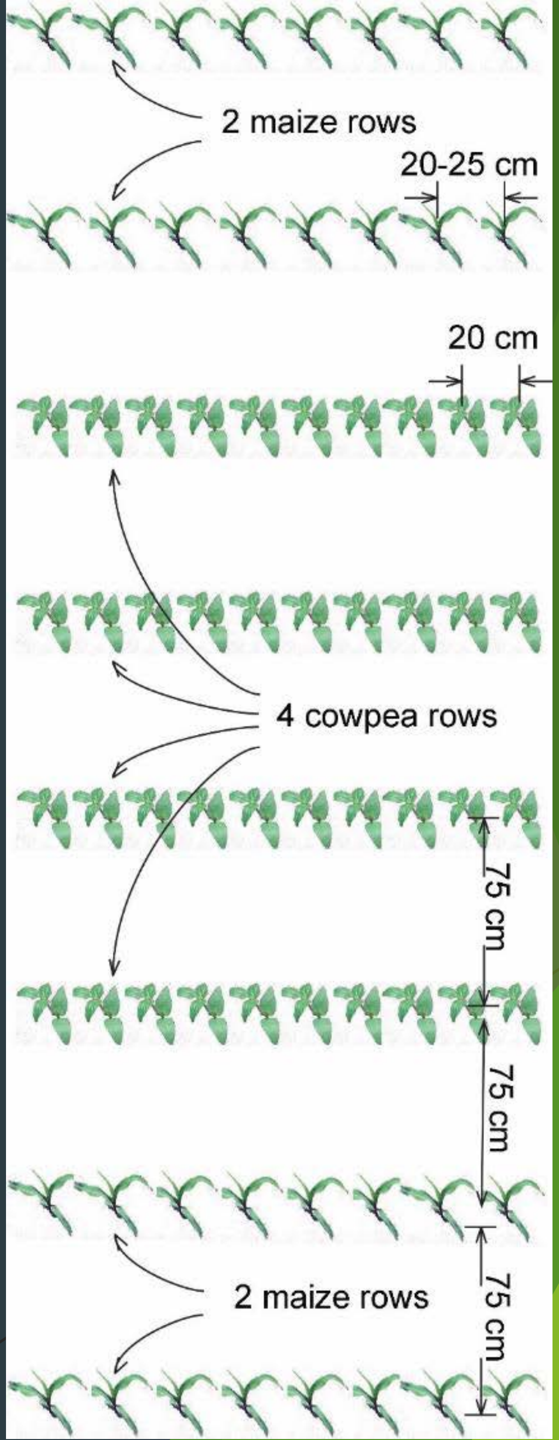
# Intercropping strategy\ legume placement options

- Plant legumes in alternating rows with a cereal crop.
  - In this way, the legume is less likely to act as a weed than if planted in the same hill/station as the cereal crop.
  - Optimize the distance between and within rows

- Plant legumes in strips of space (as in next slide)

# Placement options\alternating strips instead of single rows


An IITA (International Institute of Tropical Ag) pattern for planting maize (A) and a legume (B), modified to include cassava (C). Net return of the legume must justify less land devoted to maize. See ECHO Development Notes 133.



# “Stack” practices for a better chance of success with legume intercropping

- Add manure (consider composting it with other plant-based materials) to the soil to help retain nutrients.
- If micro-dosing mineral fertilizer, consider combining it with manure or compost to slow down N leaching.
- Target the application of amendments near plant roots---in basins or furrows. This maximizes efficiency of limited resources.

# Acknowledgements

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- **Day workers:** Alieta, Christina,Khesani, Linda, Lizzy, Joseph and Gladys

# Resources

- Fact sheets on specific legumes:
  - Tropical Forages: http://www.tropicalforages.info/index.htm
  - FAO Grassland Index: http://www.fao.org/ag/AGP/AGPC/doc/Gbase/mainmenu.htm
- Restoring the Soil: A Guide for Using Green Manure/Cover Crops to Improve the Food Security of Smallholder Farmers (Roland Bunch): http://www.fao.org/ag/ca/CA-Publications/Restoring_the_Soil.pdf