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Title:
Cowpea (*Vigna unguiculata*) Crops in Africa can Respond to Inoculation with Rhizobium

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"Rhizobium inoculants from EMBRAPA through the Africa-Brazil Innovation MarketPlace have helped double legume (cowpea) grain yields in Ghana"

-- Dr. Yemi Akinbamijo, Executive Director, FARA

INTRODUCTION

- In Africa cowpea is estimated to occupy over 11 million ha (4 million ha in Nigeria alone)
- Mean yield in Africa is between 450 and 500 kg grain ha^{-1}(FAOSTAT, 2015 - data for 2013)
- In Ghana the crop occupies approximately 200,000 ha with mean grain yield of ~450 kg/ha

INTRODUCTION

- Cowpea (*Vigna unguiculata*, Walp.) is the principal grain legume crop in the north and northeast regions of Brazil

- It occupies approximately 1.3 million ha, 95 % of which is grown in the NE region of Brazil

- The average yield is between 350 and 400 kg grain ha^{-1}

INTRODUCTION

- Cowpea is a hardy crop, tolerant to high temperatures and low soil fertility

- Rhizobium bacteria nodulate this legume and can promote large N_2 fixation inputs (Summerfield *et al*., 1977, Belane and Dakora, 2009; 2010)

- It nodulates well in almost all soils of the tropics and other regions

- Until recently in Brazil and in Africa it was assumed that as rhizobium capable of nodulating this crop were found in the soils of these regions, it was not worth inoculating the crop with selected strains

MOTIVATION FOR THIS WORK

- A team at Embrapa Agrobiologia working in the semi-arid northeast region of Brazil (late 1990s) showed that cowpea could respond to inoculation with rhizobium strain BR 3267 and increase grain yields by up to 30 % (≈50 kg N ha^{-1}) (Martins *et al*., 2003)

- A team from Lavras reported a study performed in the state of Piaui where uninoculated cowpea yielded 954 kg grain ha^{-1} and inoculation increased this by up to 28 % (Costa *et al*., 2011)

MOTIVATION FOR THIS WORK

- Further studies in this same district reported that inoculation with rhizobium could increase grain yields from 340 to 950 kg ha^{-1} (179% increase) (Soares *et al*., 2006)

- A team from Embrapa Roraima in the Amazon region also achieved increases in grain yield of cowpea due to inoculation with rhizobia from 20 to 35 % (Melo and Zilli, 2009; Zilli *et al*., 2009).

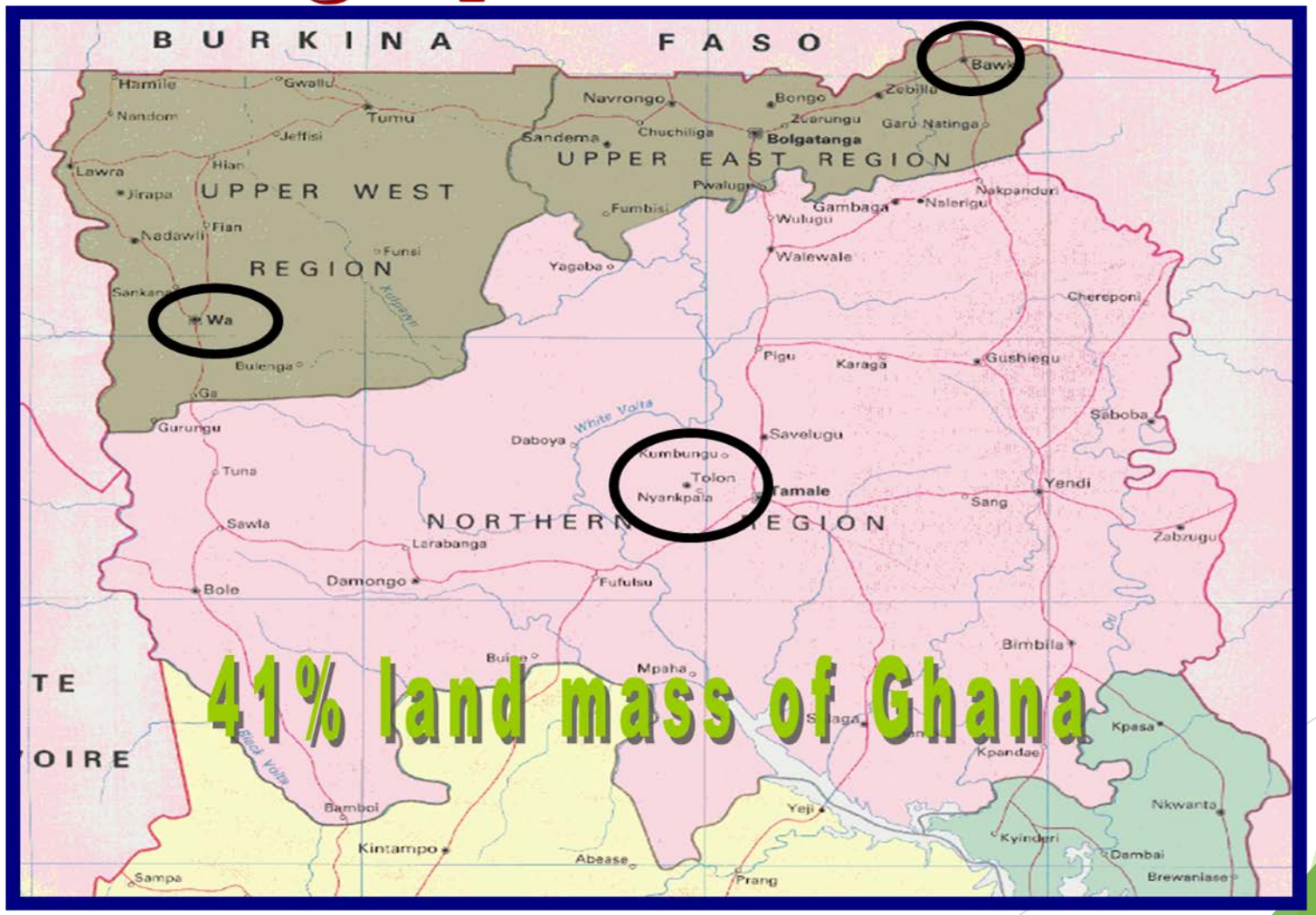
Objective

To test the effectiveness of inoculation of cowpea with inoculants made with strains of rhizobium selected in Brazil and starch/CMC polymer carrier in northern Ghana

MATERIALS & METHODS

Geographical Mandate

TRIAL AREA



TRIAL TYPES

1. On-station (2012): Two sets of trials

2. On-farm (2012): Two sets of trials

On-station Trials

- Experimental field of CSIR-SARI; Kpalsawgu (9° 24' N, 1° 00' W, 185 masl); 17 km west of Tamale

- June (17th) & August (26th), on different sites; No inoculant history

- Soil -- coarse texture; pH 6.6; organic matter: 1.2%; P:1.8 & K: 59 (mg/kg); Ca: 3.6, Mg: 1.1, H+Al: 1.4 & CEC: 5.6 ($cmol^+/kg$)

- Cowpea variety --- Padi Tuya (64-67 days; Erect; 2.5 t/ha; resistance to aphids) developed by CSIR-SARI

- 7 treatments; 5 replicates; Randomized complete block design; 5 m x 10 m plots

- All plots amended with 60 kg P_2O_5 (26 kg P) ha^{-1} as TSP

TREATMENTS -- 7

1. No inoculation, no N (control)
2. 40 kg N as ammonium sulphate
3. 80 kg N as ammonium sulphate
4. Inoculation with strain BR 3262
5. Inoculation with strain BR 3267
6. Inoculation with strain BR 3299
7. Inoculation with a mixture of strains BR 3267 & BR 3299

CARRIER MATERIAL

- Federal Rural University of Rio de Janeiro (UFRRJ) & Embrapa Agrobiologia developed an inoculant carrier medium

- Based on a polymer formed with starch and carboxymethylcellulose (CMC)

- Permits the storage of rhizobium inoculants without refrigeration with little loss in quality (numbers of viable rhizobium cells) for periods of up to 3 months (Fernandes Júnior *et al*, 2009; Silva Júnior *et al*., 2012).

SEED INOCULATION

1) Cowpea seed moistened and uniformly stirred in a bowl

2) Inoculant added at 5 kg/1 kg seed and uniformly & gently stirred

3) Inoculated seed spread on a sheet of material and air-dried for at least 30 min under a shade

Inoculation

Drying under shade

Planting

- Two plants/hill @ 60 cm x 20 cm
- All necessary agronomic practices carried out

Planting

Established trials

Sampling --- Nodules, Shoot biomass, Grain yield

- At 35 DAP--- 10 plants carefully removed whole from each plot with a spade

- Nodules collected from these plants and some placed on silica gel in penicillin vials and stored (for later isolation of rhizobia)

- Remaining nodules dried at 65^{o}C in a forced-air oven for 72 h

- At 70 DAP all shoot tissue was harvested from a central area of 4 m x 4 m of each plot & weighed using a field balance

Sampling --- Nodules, Shoot biomass, Grain yield

- All pods removed to assess total yield
- A sub-sample of all shoot biomass was taken and dried (65^{o}C; 72 h) and weighed to estimate total shoot dry matter
- Final grain yields were expressed at 13% moisture

ON-FARM TRIALS

- Two trials in 2012:
  - ✓ Between 6th and 17th June @ 11 sites (Table 1)
  - ✓ Between 16th and 24th August @ 11 sites

- Cowpea variety – Padi tuya
- Treatments:
  - ✓No inoculation (control).
  - ✓Inoculated -- rhizobium strain BR 3267
  - ✓Inoculated -- rhizobium strain BR 3299
  - ✓40 kg N ha^{-1} -- ammonium sulphate

- Plot size was 25 m x 20 m: Four plots/treatments per site
- No replication at a site – locations are replicates
- 60 kg P_2O_5 /ha (i. e. 26 kg P/ha) was added to each plot
- The trials followed standard practice of the smallholders
- Data collected on nodulation, shoot biomass & grain yield

Table 1. Locations of on-farm trials in 2012-– 1st planting

S/No.	Community	Planting Date	Harvesting Date	Latitude	Longitude
1	Choo	5th June	10th August	9° 20′ 30″ N	0° 00′ 23″ E
2	Adido	4th June	13th August	9° 18′ 03″ N	0° 01′ 03″ E
3	Kulpendulli	4th June	7th August	9° 23′ 56″ N	0° 02′ 09″ W
4	Langa	7th June	11th August	9° 34′ 52″ N	0° 52′ 59″ W
5	Maljeri	4th June	15th August	9° 30′ 17″ N	0° 01′ 35″ W
6	Savelugu	18th June	24th August	9° 36′ 57″ N	0° 49′ 27″ W
7	Susungon (Sunson)	9th June	20th August	9° 35′ 47″ N	0° 00′ 53″ W
8	Tunayilli A	3rd June	16th August	9° 22′ 12″ N	0° 58′ 25″ W
9	Tunayilli B	3rd June	16th August	9° 22′ 06″ N	0° 58′ 32″W
10	Zaazi	9th June	15th August	9° 34′ 13″ N	0° 53′ 09″ W
11	Yizegu	15th June	28th August	9° 35′ 02″ N	0° 54′ 12″ W

Table 2. Locations of on-farm trials in 2012–- 2nd planting

S/No.	Community	Planting Date	Harvesting Date	Latitude	Longitude
1	Damdu	24th August	10th November	9° 35′ 43″ N	0° 57′ 16″ W
2	Challam	24th August	14th November	9° 35′ 46″ N	0° 53′ 13″ W
3	Langa	26th August	14th November	9° 34′ 59″ N	0° 52′ 56″ W
4	Yizegu	26th August	10th November	9° 34′ 52″ N	0° 54′ 13″ W
5	Kpachi A	25th August	1st November	9° 25′ 43″ N	0° 58′ 38″ W
6	Kpachi B	26th August	1st November	9° 25′ 43″ N	0° 58′ 45″ W
7	Zang A	26th August	7th November	9° 25′ 25″ N	0° 02′ 37″ E
8	Zang B	26th August	7th November	9° 25′ 28″ N	0° 02′ 41″ E
9	Nakpachei A	26th August	15th November	9° 16′ 52″ N	0° 00′ 58″ E
10	Nakpachei B	26th August	15th November	9° 16′ 50″ N	0° 00′ 56″ E
11	Maljeri	26th August	7th November	9° 30′ 08″ N	0° 01′ 39″ W

Some mean characteristics of soils of on-farm sites

Property	1st Planting	2nd Planting
pH (1:2.5)	5.05	5.54
%OC	0.67	0.64
%N	0.06	0.07
Bray 1P (ppm)	4.40	5.38
K ($cmol^+/kg$)	0.11	0.13

RESULTS

(A) On-station results

Effect of rhizobium inoculants on nodulation

Table 3. On-station, first planting, 2012. Nodule weight and shoot biomass at 35 days after planting (DAP) and yield parameters at final harvest (70 DAP)

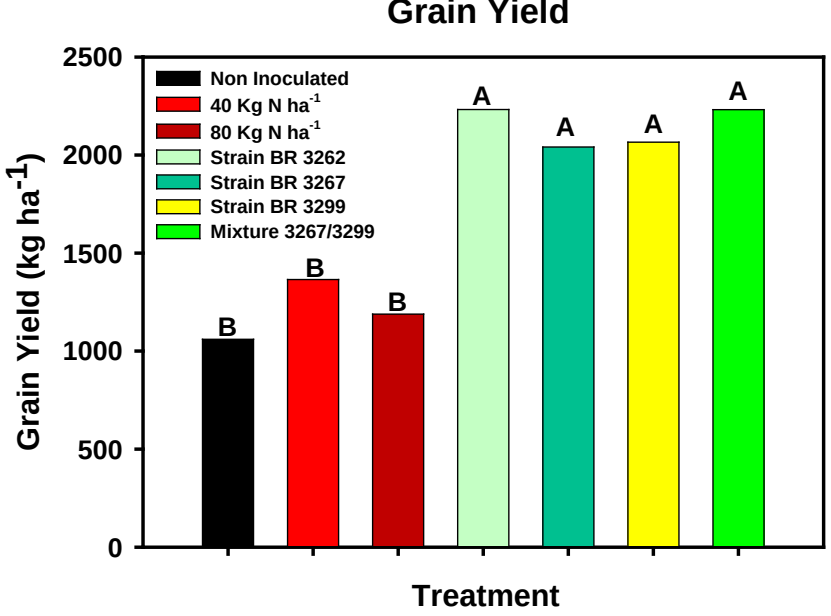
	35 DAP		70 DAP (Final Harvest)	
TREATMENT	Nodule wt. (mg/plant)	Shoot biomass (g/plant)	Shoot biomass (kg/ha)	Grain yield (kg/ha)
Noninoculated	267 c	7.8 c	2288 de	1060 b
40 kg N/ha	67 d	19.2 a	1955 e	1365 b
80 kg N/ha	45 d	16.6 b	1928 e	1888 b
Strain 3262	504 ab	6.8 c	3365 cd	2232 a
Strain 3267	628 ab	6.4 c	4821 ab	2041 a
Strain 3299	476 b	7.0 c	4116 bc	2066 a
Mixed Strains 3267/3299	660 a	6.8 c	5884 a	2232 a
CV (%)	34	17	25	28

Values are means of five replicates. Means within the same column followed by the same letter are not different at $p < 0.05$ (Student 'LSD' test)

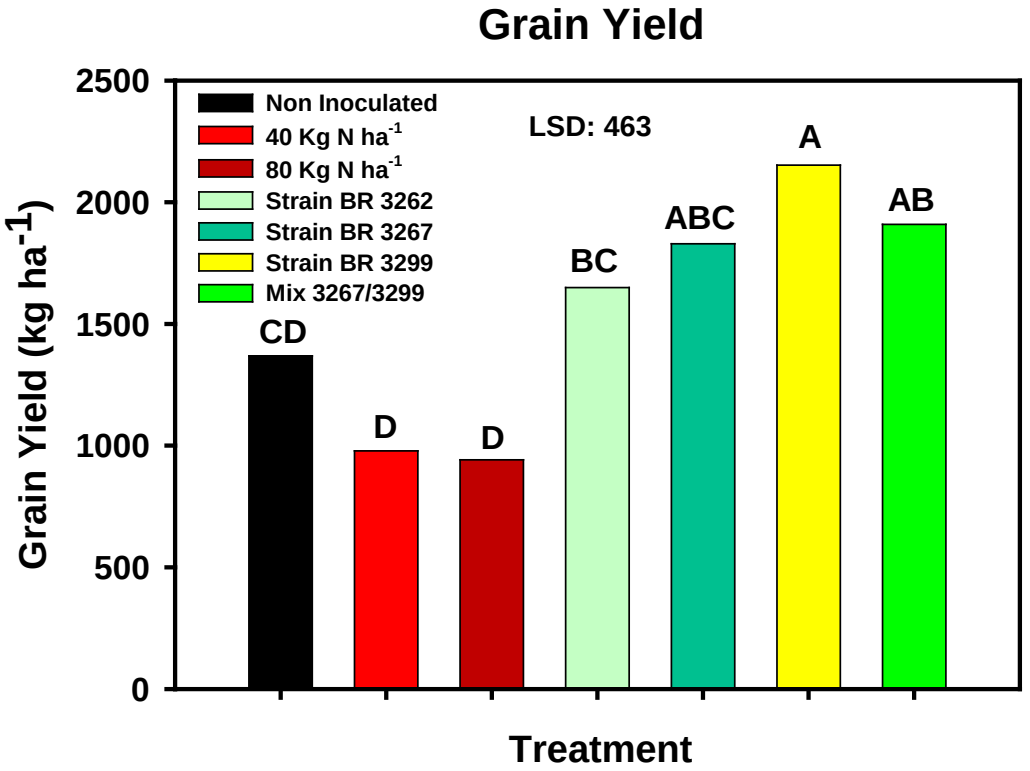
Table 4. On-station, 2nd planting, 2012. Nodule weight and shoot biomass at 35 days after planting (DAP) and yield parameters at final harvest (70 DAP)

	35 DAP		70 DAP (Final Harvest)	
TREATMENT	Nodule wt. (mg/plant)	Shoot biomass (g/plant)	Shoot biomass (kg/ha)	Grain yield (kg/ha)
Noninoculated	170 c	7.8 c	2255 cd	1368 cd
40 kg N/ha	156 c	19.4 a	1923 d	978 d
80 kg N/ha	90 c	16.8 b	1896 d	942 d
Strain 3262	530 a	6.8 c	3333 bc	1649 bc
Strain 3267	318 b	6.8 c	4788 ab	1829 abc
Strain 3299	298 b	7.2 c	4083 abc	2153 a
Mixed Strains 3267/3299	399 b	7.0 c	5852 a	1909 ab
CV (%)	35	19	25	23

Values are means of five replicates. Means within the same column followed by the same letter are not different at $p < 0.05$ (Student 'LSD' test)



On-station trial 2012 (First planting): Grain yield



On-station trial 2012 (Second planting): Grain yield

Fig. 1

1ST PLANTING – 35 DAP (TABLE 3)

- Without inoculation, dry weight of nodules averaged 267 mg plant^{-1} but this was greatly increased by inoculation with any of the rhizobium strains
- Nodule wt. more than doubled with strain BR 3267 and the mixture of BR 3267 and BR 3299
- Addition of N fertilizer depressed nodulation
- Shoot dry matter accumulation was far higher where N fertilizer was added

1ST PLANTING --- HARVEST (Table 3; Fig. 1)

- At the final harvest, the shoot biomass was significantly increased by inoculation except with the BR 3262.

- With the mixed inoculant (BR 3267+BR 3299) this increase was over 150 %

- Grain yield without inoculation was very good at over 1000 kg ha^{-1} and there was a non-significant increase in yield with the addition of N fertilizer

- Addition of any of the inoculants highly increased grain yield producing over 2000 kg grain ha^{-1} (ranging b/n 93-111% increase)

2ND PLANTING --- 35 DAP (TABLE 4)

- Without inoculation, dry weight of nodules averaged 170 mg plant^{-1}, somewhat lower than in the first planting
- The nodule weight was once again greatly increased by inoculation with of any of the rhizobium strains
- Nodule weight more than tripled with the strain BR 3299 (530 mg plant^{-1})
- The other inoculants increased nodule dry weight to over 300 mg plant^{-1}
- Again, the addition of N fertilizer depressed nodulation

2ND PLANTING --- HARVEST (TABLE 4; Fig. 1)

- Plant biomass was significantly increased by inoculation except with BR 3262
- With the mixed inoculant (BR 3267+BR 3299), this increase was 160%
- Grain yield even without inoculation was very good reaching over 1300 kg/ha
- There were non-significant decreases in biomass & grain yields with the addition of N fertilizer
- There were significant increases in grain yield when the plants were inoculated with BR 3299 or the combination of BR 3267 and BR 3299

(B) ON-FARM RESULTS

Inoculated

Non-Inoculated

40 kg N/ha

Table 5. On farm trials, first planting 2012. Nodule weight at 35 DAP and yield parameters at final harvest

	35 DAP		70 DAP	
TREATMENT	Nodule wt. (mg/plant)	Shoot biomass (g/plant)	Shoot biomass (kg/ha)	Grain yield (kg/ha)
Non Inoculated	322 b	2510 b	1882 ab	1162 b
40 kg N ha^{-1}	138 c	**5844 a**	1185 b	1086 b
Strain BR 3267	**522 a**	2563 b	**3724 a**	**1722 a**
Strain BR 3299	**482 a**	2401 b	**2105 ab**	**1594 a**
CV (%)	23	11	18	35

Values are means of eleven replicates. Means within the same column followed by the same letter are not different at $p < 0.05$ (Student 'LSD' test)

On-farm 1st planting 2012

- Nodule weight decreased with the application of N fertilizer but at most sites increased with inoculation (Table 5)

- At final harvest shoot dry matter was greatly increased at all sites in response to the addition of N fertilizer but grain yield was hardly affected (Table 5)

- However, grain yield was increased on average by 430 to 560 kg grain ha^{-1} by BR 3267 and BR 3299, respectively, reaching a mean for all trials of over 1600 kg ha^{-1}.

Table 6. On farm trials, 2nd planting 2012. Nodule weight at 35 DAP and yield parameters at final harvest

	35 DAP		70 DAP	
TREATMENT	Nodule wt. (mg/plant)	Shoot biomass (g/plant)	Shoot biomass (kg/ha)	Grain yield (kg/ha)
Non Inoculated	313 b	1398 b	2677 b	891 b
40 kg N ha^{-1}	152 c	1596 b	**3280 a**	985 b
Strain BR 3267	**463 a**	**1969 a**	2417 b	**1386 a**
Strain BR 3299	**478 a**	**2071 a**	2498 b	**1459 a**
CV (%)	21	21	12	23

Values are means of eleven replicates. Means within the same column followed by the same letter are not different at $p < 0.05$ (Student 'LSD' test)

On-farm 2nd planting 2012 --Tab. 6

- Second planting results were very similar to 1st planting results
- Nodulation was depressed by the application of N fertilizer and significantly increased by inoculation
- A large and significant increase in total dry matter accumulation with application of N fertilizer but grain yield was not increased
- However inoculation with rhizobia increased grain yield by more than 500 kg ha^{-1}, with yields reaching 1380 to 1450 kg ha^{-1}.

SUMMARY

Benefits from Rhizobium Inoculations (%)

	Grain yield kg/ha)		Biomass (kg/ha)		Nodule wt. (mg/plant)	
Period	On-station	On-farm	On-station	On-farm	On-station	On-farm
1st Planting	93-111	37-48	80-157	12-98	78-147	50-62
2nd Planting	40-57	56-64	81-160	No effect	75-212	48-53

CONCLUSION

Cowpea can respond remarkably to inoculation with rhizobium when highly effective rhizobium strains are used and

The decision to use a mixed inoculum would seem to be a good strategy to maximize inoculation responses and this is the practice recommended in Brazil for soybean inoculants

When the proper strains are used, rhizobium inoculation can be used to boost cowpea productivity among smallholder farmers in northern Ghana and this can help reduce food insecurity, especially child malnutrition in the region.

WAY FORWARD

- Using higher doses of inoculants from these strains
- Integrated inoculation: with inoculants of root growth-promoting organisms
- Integration with organic & inorganic fertilizers

ACKNOWLEDGMENT

- Ministry of Food and Agriculture, Ghana
- Smallholder farmers
- Africa-Brazil Innovation MarketPlace

THANK YOU ALL FOR YOUR AUDIENCE