Enhancing Food Security through Improved Productivity, Nutrition and Marketing of Chickpea in Central and Western Ethiopia

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Ethiopian Agricultural System

- It accounts for half of the GDP & 90% of the exports as well as employment of 85% of the work force;
- The smallholder farmers cultivate 95% of the cropped area;
- This farming practice are generally characterized by low yield per unit area;
- The main cause for lower productivity is the use of local landraces along with traditional management practices & effect from biotic & abiotic stress.

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Soil Acidity and Al Toxicity

- Soil acidity is an important environmental factor.
- influence plant growth & can seriously limit crop production.
- ~ 50% of potentially arable land area of the world is known to be acidic in nature
- Up to 60% of acid soils found in developing countries
- Al+3 is a commonly toxic metal pollutant worldwide.

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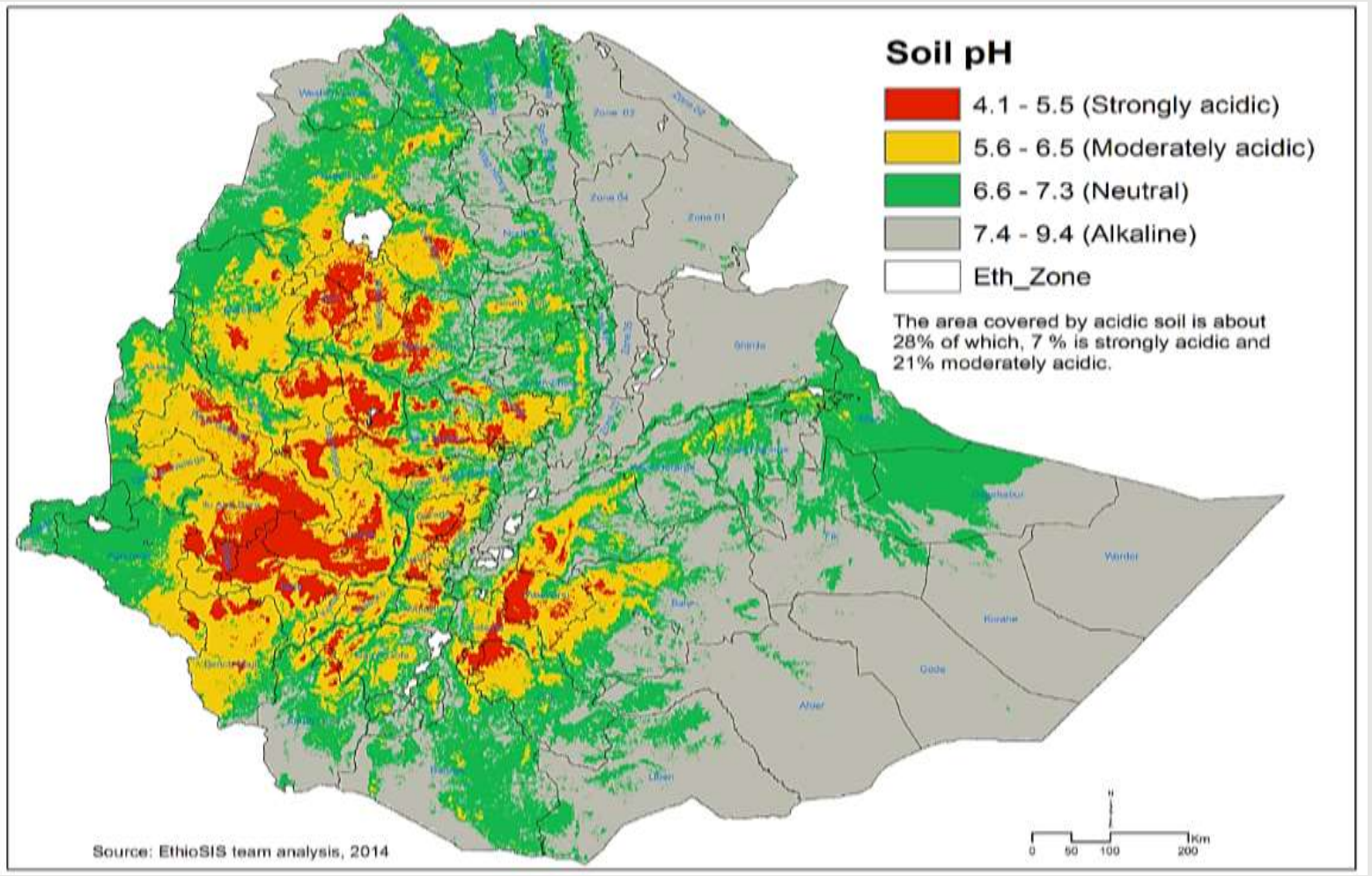
Soil Acidity Status of Ethiopia



- In Ethiopia, soil acidity is the major productivity problem that has not been addressed in depth.

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Soil Acidity Status ….

- According to EthioSIS (2014) report, about 40% of total land area or 28% of arable land is estimated to be acidic.
  - ✓ ~ 27.7% is moderately acidic (pH 5.5. – 6.7)
  - ✓ 13.2% is strongly acidic (pH < 5.5)
- Significant yield reductions & even complete loss of production have been reported in several parts of the country.
- Given the fact that soil acidity is an ongoing process, the problem has the potential to get worse if immediate action will not be taken.

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Attempts to minimize the effect of soil acidity

- The MoA has embarked on a massive soil reclamation program.
- Liming of the soil combined with the application of inorganic fertilizer improved the quality of the top soil to some extent;
- But this approach was found to be too expensive & Not sustainable for subsistence farmers.
- Given the limited access of most farmers to phosphate fertilizers as well as liming service in Ethiopia, it is necessary to look for other options.

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Attempts to minimize …

- For both logistics as well as economic reasons, it is not possible for the resource poor farmers to purchase & apply high rates of lime & mineral fertilizers
- Liming is only possible for surface soil & does not remedy the sub-soil acidity (Tesfaye *et al.*, 2001).

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Other solutions

- The responses of plants to soil acidity/Al toxicity are highly variable between & within the species;
- Varied responses observed from different genotypes of a same species including rhizobacteria;
- Therefore, looking for tolerant crops such as chickpea based on their physiological & genetic base has been found useful.
- However, genetic potential of Ethiopia's chickpea to Al tolerance has not been evaluated.

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Objectives of the current project

- ***Objective 1:*** To phenotype chickpea genotypes (populations derived from crosses, local landraces & improved variety). Plants will be phenotyped for tolerance to aluminum toxicity & enhanced seed nutrition;
- ***Objective 2***: To evaluate the symbiotic effectiveness of *Mesorhizobium* strains isolated from different chickpeas field under Aluminum toxicity stress conditions & develop PSMs inoculant;
- ***Objective 3*:** To undertake seed system study, marketing & value-chains of chickpea in terms of the key players;
- ***Objective 4:*** To train & educate a gender-diverse group of young scientists (2 PhD & 2 MSc) from Ethiopia NARS.

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Research Approach

Component 1: Hydroponic Screening of Ethiopian Chickpea (*Cicer arietinum* L.) Genotypes for Tolerance to Aluminum Toxicity

- 29 chickpea genotypes: 24 nationally released improved varieties, four advanced lines & one local variety from Wollega zone were used.

- Field Screening of tolerant chickpea germplasms at Nedjo & Arjo, western Ethiopia.
- Breeding experiment at Debrezeit
- Multi-location trial of advanced genotypes
- Genome analysis

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- **Optimization of Aluminum Concentration**

Local Variety

Akaki

Natoli

Dalota

Minjar

Fig 2. Application of lime at Nedjo site.

Planting of chickpea at Nedjo &Arjo site

Research Approach

Component 2:

- **Genetic Diversity and Evaluation of Biological Nitrogen Fixing and Phosphate Solubilizing Mesorhizobium Chickpea (*Cicer arietinum* L.) from Acidic Soils of Ethiopia.**

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Collection

Collection included:-

- Plant root nodule
- Soils samples
- At 79 farmers field
  - ✓ Western, central & northern
- 2015/2016 cropping seasons

Isolation

200 live culture rhizobia

Screening for Low pH tolerance and P solublization

- ✓pH 4 to 7
- ✓Phosphate solublization on Tricalcium phosphate

- ✓ Ferrous phosphate (FP) ($FePO_4$)
- ✓Aluminum phosphate (AP) ($AlPO_4$)

DNA extraction

96 genome DNA

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Cont…

WGS (Whole Genome Sequencing)

Phenotypic characterization

- ✓ Utilization of different of C & N sources
- ✓ Resistance to antibiotics and heavy metal, NaCl and temperature tolerance.
- ✓ PGP properties

Greenhouse at DZARC

Variety: Natoli and DZ-ck-2011 s-2-0042

Strains: 18 identified and Nationally used reference strain CP41

Positive: 0.05% KNO3 (w/v)

- Control: No inoculant (water)

Nutrient: N-free solution supplied as nutrient source

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Research Approach

Component 3: Seed System, Marketing and Value Chain Analyses of Chickpea in the Central Highlands of Ethiopia

- This study had two phases.
  - The first phase addressed chickpea value chain analysis and data was collected from farmers and different market actors including traders, processors and facilitating organizations
  - The second phase addressed chickpea seed system and chickpea marketing. different chain actors including rural assemblers, whole sellers, retailers, market facilitators and processors at all administrative levels as well as farmer's cooperatives were addressed.
  - For Analysis, Integrated Value-chain development, value-chain stakeholder mapping & Business canvas modeling were used.

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Key results of research/project

❖ **Component 1: Hydroponic Screening...**

- Lower levels of Al^{3+} conc. (25 µM), did not inhibit root & shoot length of the genotypes compared to the control (0 µM).
- When increasing Al^{3+} conc. from 50 to 200 µM, there was a sharp & continuous decline in the TRL although the degree varied among genotypes.
- 120 µM Al3+ concentration was selected as an optimum concentration for further screening purpose.
  - It discriminates the genotypes & classified them in to different tolerance levels (tolerant, intermediate & susceptible).
  - *TRL could serve as an important screening tool in the further screening of 560 chickpea germplasms.*

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- Among six genotypes used, **Farmer's variety** obtained from **Wollega zone,** was found to be the most Al toxicity tolerant genotype.

TOLERANT

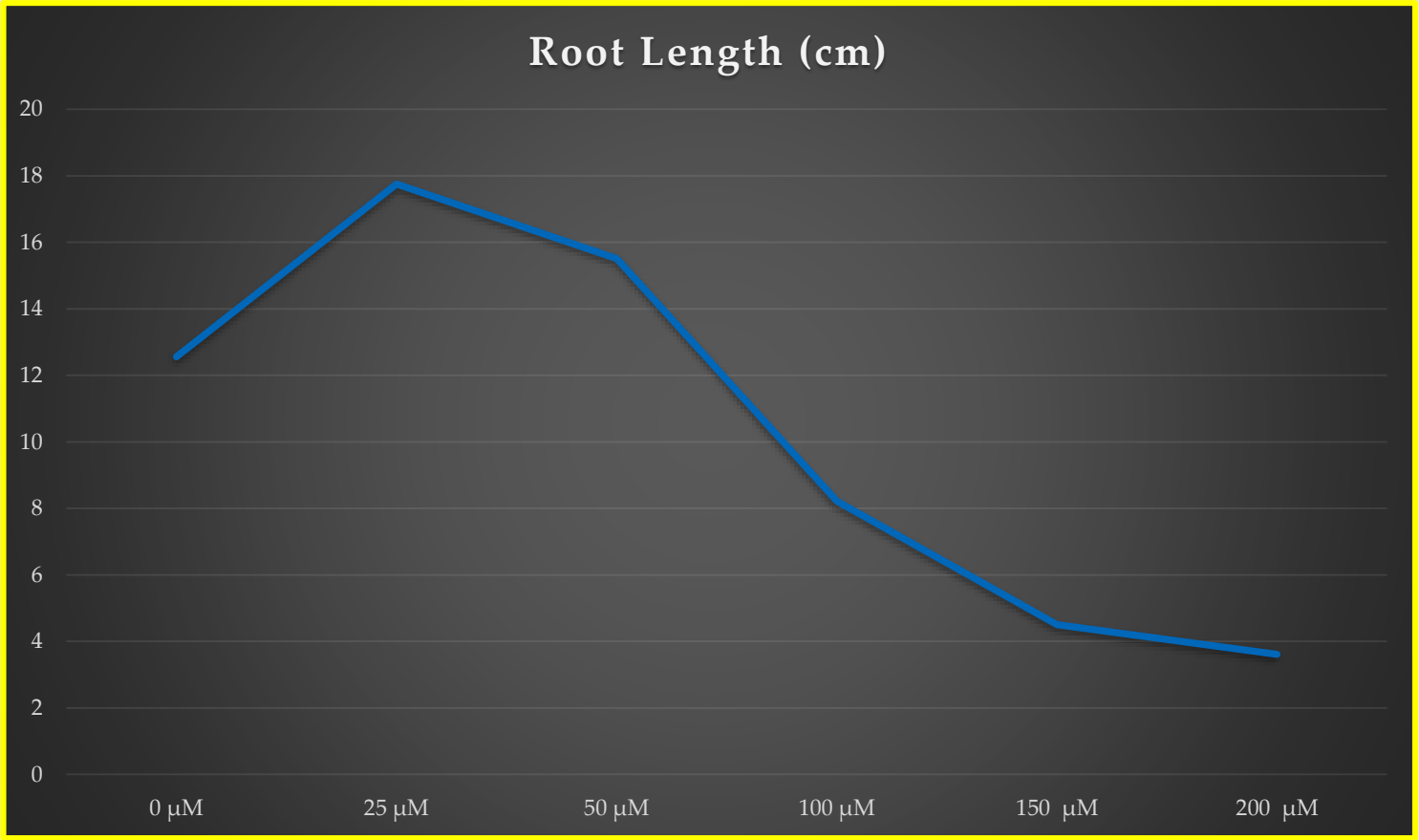
Akaki was found to be the least tolerant or the most susceptible genotype.

SUSCEPTIBLE

✍ Akaki & LV will be used as a reference genotypes for further screening of Ethiopian chickpea germplasms.

Key Results…

TRL of chickpea genotypes were significantly reduced with increasing level of Al^{3+} concentration



Mean Tap Root length of six chickpea genotypes grown in a nutrient solution for six days under 0, 25, 50,100, 150 & 200 µM aluminum concentration.

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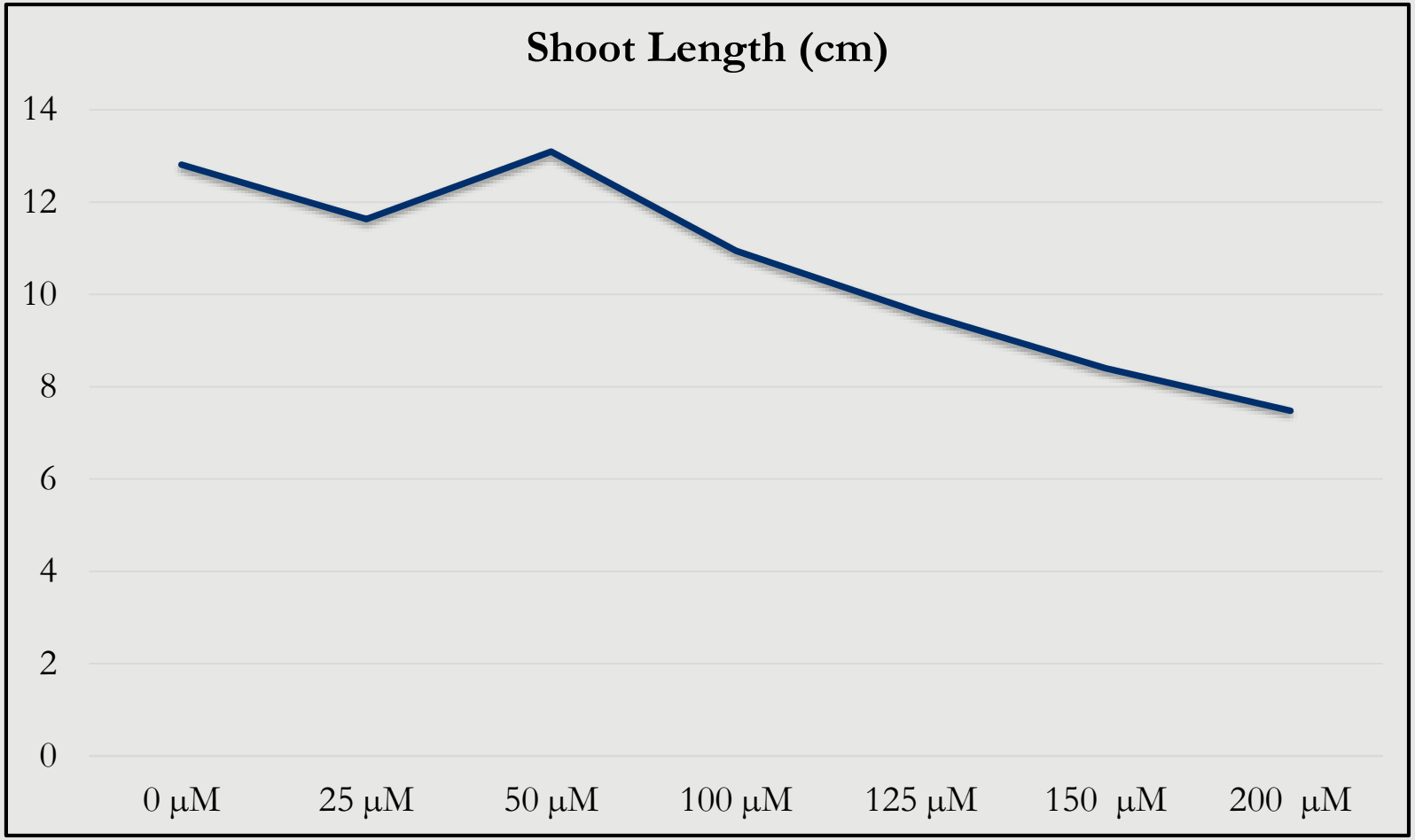

Mean Shoot length of six chickpea genotypes grown in a nutrient solution for six days under 0, 25, 50,100, 150 & 200 µM Al conc.

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Ongoing/future activities

- F1 hybrid seeds obtained from six tolerant and one susceptible are plant at Debrezeit to harvest F2 seeds. Thus, the crossing experiment was completed as per planned.
- Natoli, which is a released variety, can be promoted as Al toxicity tolerant soon.
- Pot experiment will be carried out at Debrezeit lath house.
- Multi-location Trial of Advanced Genotypes
- Genome Analysis At UC Devis, USA

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Lath house and field experiments at Debrezit

Key results of research/project

Component 2:

- **Genetic Diversity and Evaluation of Biological Nitrogen Fixing and Phosphate Solubilizing Mesorhizobium Chickpea (*Cicer arietinum* L.) from Acidic Soils of Ethiopia.**

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16S rRNA sequence analysis

Multilocus sequence analysis

- ✓ 68 strains identified as *Mesorhizobium*
- ✓ Amplicon sequencing identified distinct phylotypes
- ✓ Whole genome diversity metrics & average nucleotide further resolved distinct clades (Fig.Tree)
- ✓ The vast majority of strains share highest affinity with *Mesorhizobium* species not previously known to nodulate chickpea.

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Greenhouse…

Strains	Symbiotic effectivness (%) at pH 4		Symbiotic effectivness (%) at pH 5		Symbiotic effectivness (%) at pH 7	
	Natoli	DZ-2012-CK-20113-2-0042	Natoli	DZ-2012-CK-20113-2-0042	Natoli	DZ-2012-CK-20113-2-0042
AtACR15star	87.7^{d}	88.4^{bac}	81.3^{ba}	95.5^{ba}	95.9^{a}	93.5^{a}
AtACR90	82.6^{g}	82.1^{bac}	68.6^{bedc}	78.7^{dc}	57.5^{fdeg}	72.5^{bdec}
AtACR55	78.5^{j}	75.8^{bdac}	60.65^{fedc}	62.8^{e}	47.8^{feg}	60.4^{dec}
AtACRAR45 2	77.5^{k}	85.2^{bac}	68.7^{bedc}	62.8^{e}	40.0^{fg}	72.5^{bdec}
AtACR117L	101^{b}	98.9^{ba}	84.3^{ba}	94.5^{ba}	64.6^{dec}	79.8^{bac}
AtACR71	84.7^{e}	98.9^{ba}	69.5^{bdc}	93.5^{ba}	81.5^{bac}	96.3^{a}
AtACR89	80.6^{i}	84.2^{bac}	54.5^{fed}	99.9^{a}	78.1^{bdac}	58.8^{de}
AtACR30 $_2$star	73.5^{m}	73.7^{bdac}	46.5^{f}	87.1^{bc}	58.4^{fdc}	54.8^{e}
AtACR66	81.6^{h}	63.1^{dc}	59.1^{fed}	68.1^{ed}	47.4^{feg}	63.7^{bdec}
AtACR16star	81.6^{h}	89.95^{bac}	68.7^{bedc}	69.7^{ed}	50.9^{feg}	60.8^{dec}
AtACR40L	102^{a}	103^{a}	83.5^{ba}	97^{ba}	86.5^{ba}	79.05^{bac}
AtACR200M	92.8^{c}	85.25^{bac}	88.1^{a}	95.5^{ba}	65.6^{bdec}	81.8^{ba}
AtACR200s	76.5^{l}	72.6^{bdc}	77.8^{bac}	92.1^{ba}	54.9^{feg}	66.9^{bdec}
AtACR142	80.6^{i}	75.8^{bdac}	59.5^{fed}	88.6^{bac}	45.2^{feg}	60^{dec}
AtACR64	82.6^{g}	82.1^{bac}	67.9^{bedc}	93.1^{ba}	78.1^{bdac}	62.1^{bdec}
AtACR102	72.4^{n}	70.5^{bdc}	59.5^{fed}	90.1^{bac}	42.1^{fg}	77.7^{bdac}
AtACR104	83.6^{f}	80.0^{bdac}	61.1^{fedc}	85.6^{bc}	51.5^{feg}	62.1^{bdec}
AtACR152	77.5^{k}	85.2^{bac}	59.5^{fed}	68.1^{ed}	45.2^{feg}	60.4^{dec}
[illegible]	63.3^{o}	52.1^{d}	51.7^{fe}	68.3^{ed}	36.5^{g}	52.4^{e}

➢Plants inoculated with 18 diverse strains showed significant($p < 0.001$) symbiotic effectiveness compared to control plants treated with either nationally used commercial inoculants or KNO_3 (Table).

➢Since these strains have exhibited interesting features of highly effective nitrogen fixation at low pH, the following isolates AtACR15star, AtACR40L, AtACR200M and AtACR117L were selected for soil culture study under green.

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Future activities

- Analysis for soil culture study after harvesting and recording relevant parameters.

- Field experiments will be conducted at two locations: Holleta and Arjo, in central and western parts of Ethiopia during the main cropping season at the end August – November, 2018.

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Key results of research/project

Component 3:

Seed System, Marketing and Value Chain Analyses of Chickpea in the Central Highlands of Ethiopia

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Key results …

- The formal seed system for chickpea is poorly developed and most farmers rely on their own farm saved seed (harvest of the last season), neighboring farmers or the local grain markets.
- Supply chains of chickpea are also poorly organized and products move less quickly at high transaction and transport costs between the different trade levels.
- There are four main actors: input providers, producers, traders (collectors, wholesalers and retailers), local processors and consumers.

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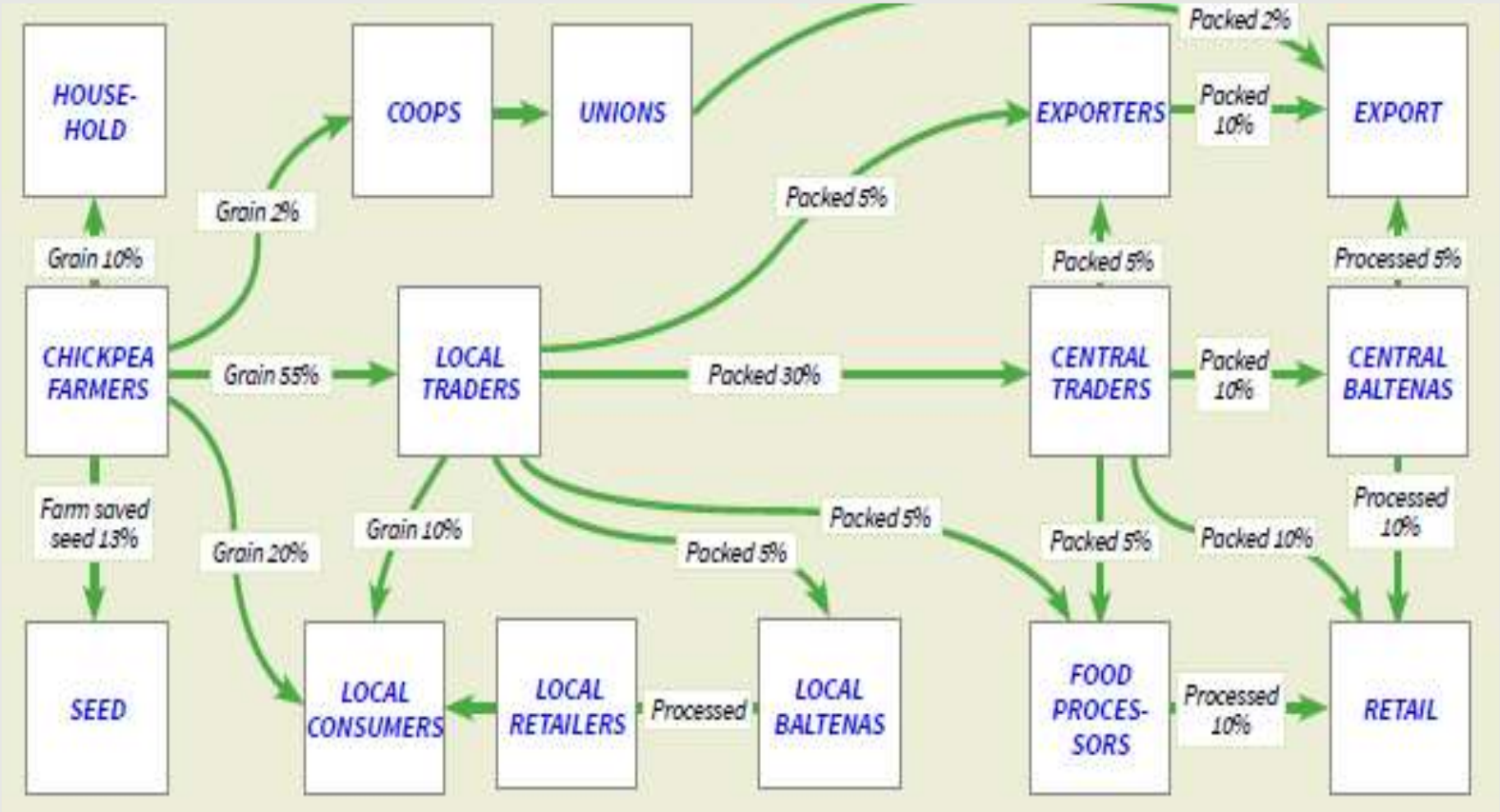
Key Results…



Chickpea value chain in East Showa zone (Adaa, Gimbichu, and Lume districts)

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Challenges

- Shortage of chemicals and reagents in the local market;
- Poor quality of chemicals and reagents from local market;
- Electrical power interruption.
- Social unrest disrupted field screening experiment mainly in Oromia & Neighboring areas
- Slow release of funds

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PEER Project Team

Research Team

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Thank You!