Enhancing nitrogen use in crops: A translational research approach
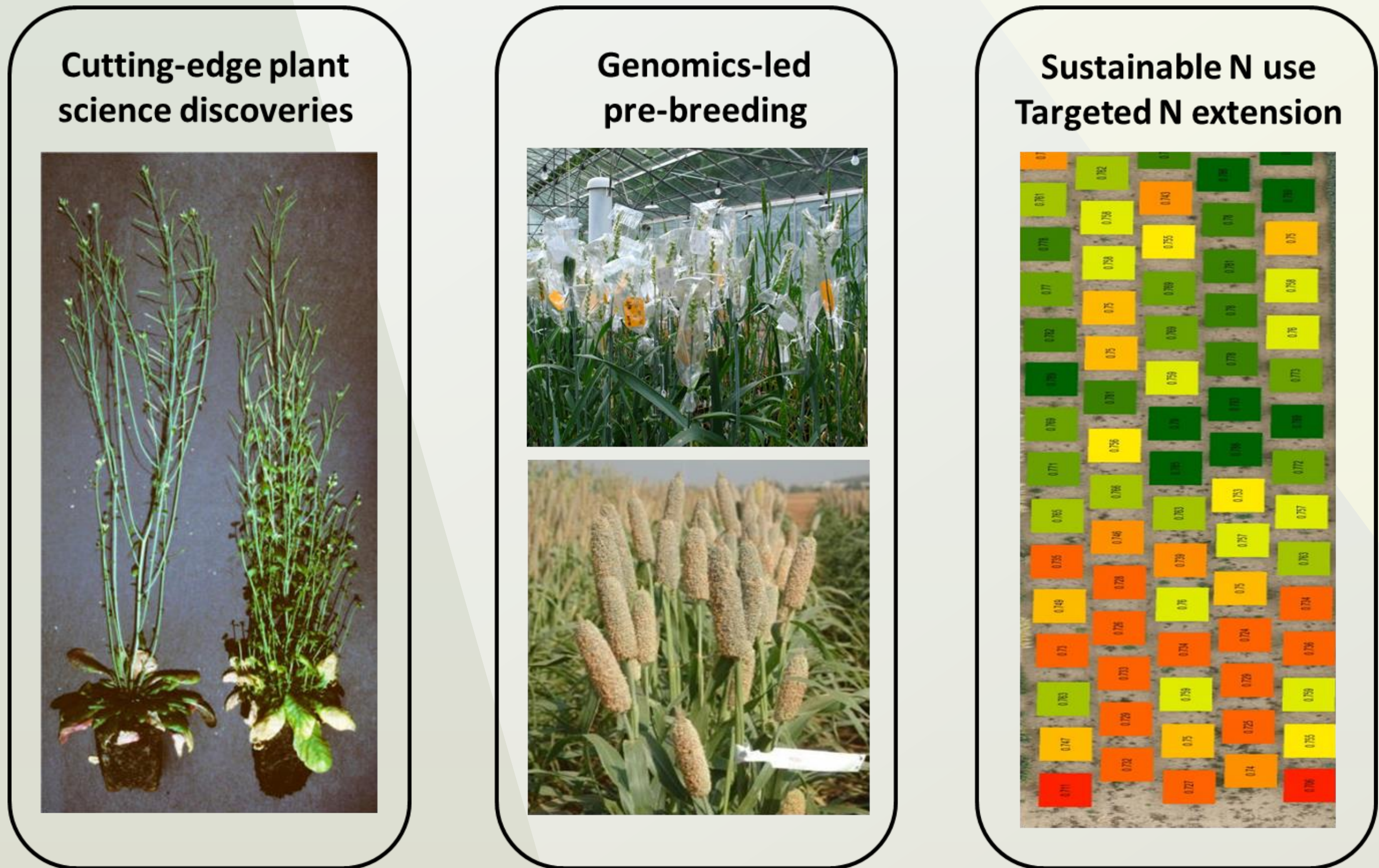
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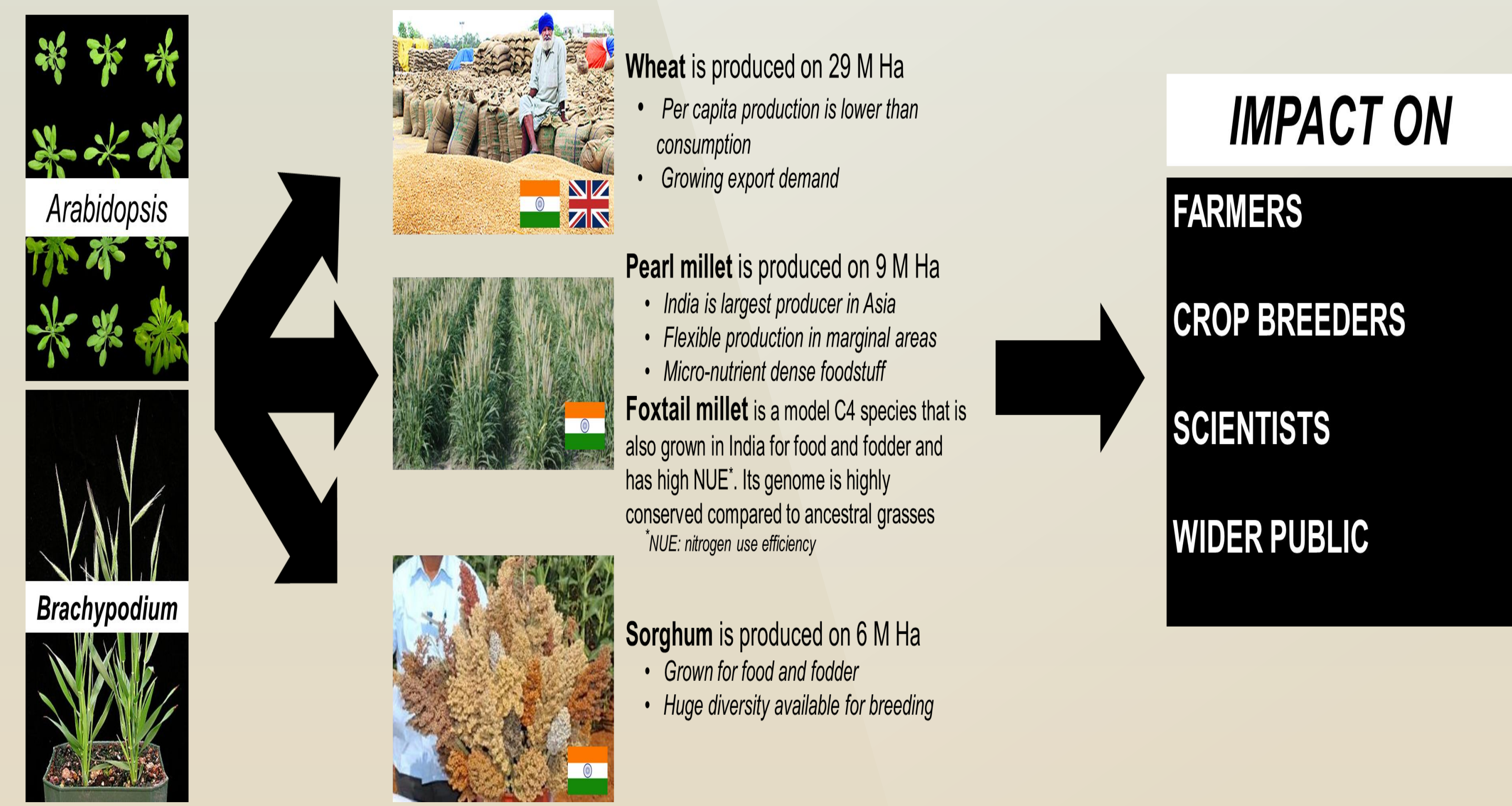
Abstract

Optimization of reactive nitrogen (N) use by crops has assumed great significance in recent years due to increasing fertilizer costs and severe environmental pollution due to N losses from the soil. This is particularly relevant for developing countries where farmers have limited financial resources and are confronted with the need for food security for an increasing population amidst climate change. The study reported in this paper is part of the Cambridge – India Network for Translational Research in Nitrogen (CINTRIN) which aims to translate our recent understanding of developmental N use in model plants such as *Arabidopsis* and *Brachypodium* to foxtail millet, wheat, sorghum and pearl millet by screening for nitrogen insensitive (NIS) ideotypes, analysing their relative N utilization, yield potential and subsequently, establish candidate genes regulating N use. Among the four studied crops, foxtail millet (*Setaria italica* L.) is a C$_4$ model cereal that requires very low growth inputs, and is perfectly adapted to tropical semi-arid climate. The crop has one of the highest nutritional indices for human consumption, making it suitable for arid and semi-arid environments. In the present study, we propose to employ high-throughput phenomics platforms to examine agronomically important traits in 200 genetically and geographically diverse accessions of foxtail millet and use next generation comparative genomics and bioinformatic tools to identify candidate genes/QTLs regulating N use. We also propose to compare and analyse the variation in physiological N uptake/ use and allocation to grains by using high throughput 13N/15N partitioning experiments to identify parallels with nitrogen sensitive (NS) and nitrogen insensitive (NIS) genotypes. The overall objectives of the study are to couple the molecular basis of plant development to the physiology of N uptake and partitioning, thereby defining new NIS ideotypes and generate valuable information on cultivar-specific N fertiliser requirements, which will have direct benefits to farmers.

CINTRIN will provide innovative approaches to tackle crop biological N use

Cutting-edge plant science discoveries

Genomics-led pre-breeding

Sustainable N use Targeted N extension

CINTRIN: a truly translational centre

Arabidopsis

Brachypodium

Wheat is produced on 29 M Ha
- Per capita production is lower than consumption
- Growing export demand

Pearl millet is produced on 9 M Ha
- India is largest producer in Asia
- Flexible production in marginal areas
- Micro-nutrient dense foodstuff

Foxtail millet is a model C4 species that is also grown in India for food and fodder and has high NUE*. Its genome is highly conserved compared to ancestral grasses
*NUE: nitrogen use efficiency

Sorghum is produced on 6 M Ha
- Grown for food and fodder
- Huge diversity available for breeding

IMPACT ON
FARMERS
CROP BREEDERS
SCIENTISTS
WIDER PUBLIC

CINTRIN: Network

Flowchart

NATURAL VARIATION IN N USE IN FOXTAIL MILLET

- **High Throughput Phenotyping** → **Qualitative and Quantitative Traits + Yield analysis** → Comparative metabolome → **NS and NIS ideotypes** → Comparative Proteome
- **High Throughput Transcriptome analysis** → **Gene clusters/ metabolic pathways regulating N use** → **Candidate Genes**
- **High Throughput Genotyping** → **Genome Wide Association Studies (GWAS)** → **Mapped QTLs**

Genotype X Environment Interaction studies

Farmer interaction

NIS performance Validation in field (Yield penalty analysis)

Breeding for N efficient High yielding genotypes (RIL/NIL etc.)

N residue Analysis in soil

Model for optimal N use

N efficient high yielding cultivar

Precision agriculture