

Biotechnology: A Case for Investment in Alternative Staple Crops

Investigating the status and limitations in genetic improvement for orphan crops



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Background

Ten years ago, Professors Rosamond Naylor and Walter Falcon published a landmark study making the case for increased investment to improve orphan, or understudied, crops (Naylor et. al, 2004). Financial resources have focused mainly on major international crops, e.g. maize, rice, wheat, and soybean. In contrast, “orphan” crops, including millets, sorghum, cowpea, and various indigenous vegetables, fruits, roots, and tubers, tend to be locally important, but receive little public or private investment due to relatively smaller markets. Nonetheless, these crops are nutritious, valued culturally, often adapted to harsh environments, and diverse in terms of their genetic, agroclimatic, and economic niches. The study examined the importance of different orphan crops, particularly in Sub-Saharan Africa, and the impact that investments in these crops might have on food security given projected population growth over the next 30 years. Improvements in orphan crops have the potential to benefit poor regions that do not have substantial private sector investment.

1 billion people live on less than \$1 per day, and suffer from chronic hunger (Smil, 2000). Poverty is worst in rural areas where agriculture is a leading source of incomes and employment, while investments by the public and private sectors in agriculture are extremely low. With populations growing rapidly in developing countries, there is an increased sense of urgency to address and alleviate hunger and poverty. Investment in orphan crops may be a key mechanism to improve agriculture, to break the cycle and feed an increasing number of undernourished populations in these countries.

Research Question

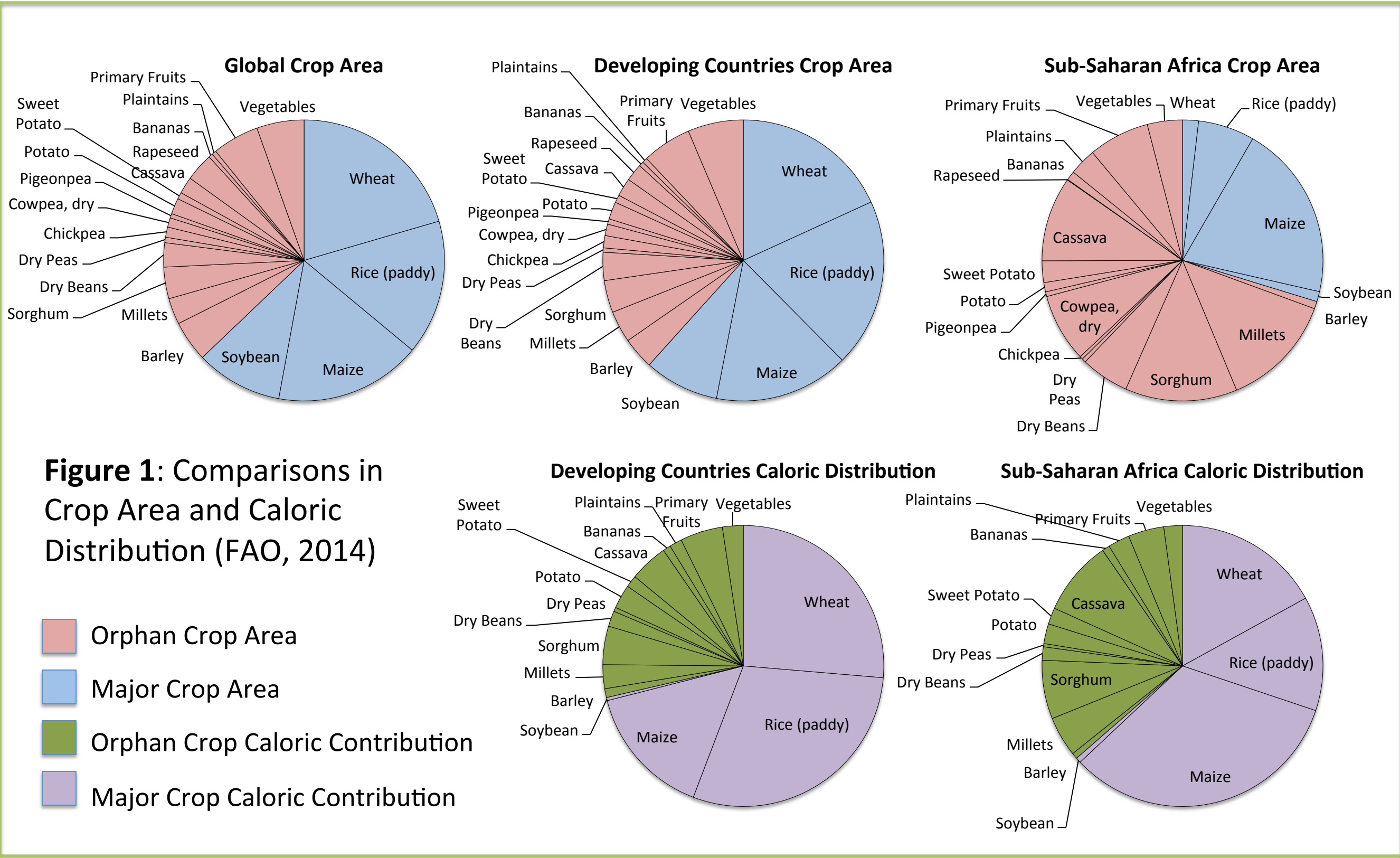
What is the state of orphan crop research today? What are its limitations?

Genome Editing Biotechnology Available Today


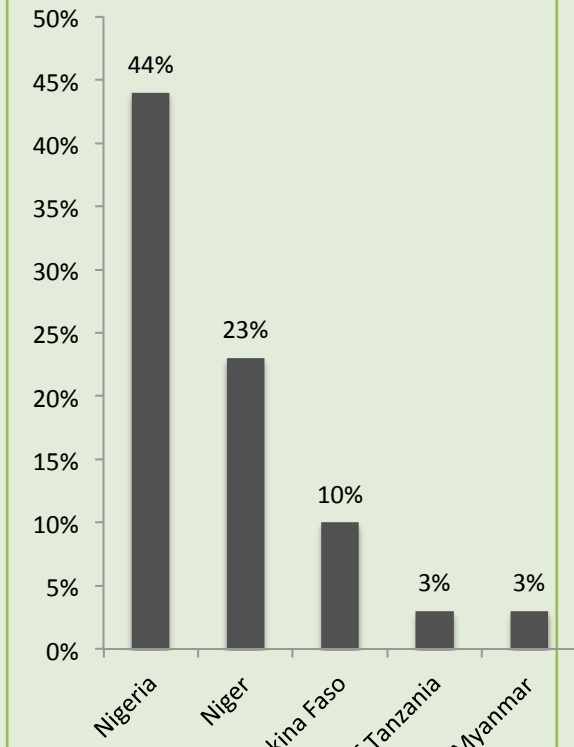

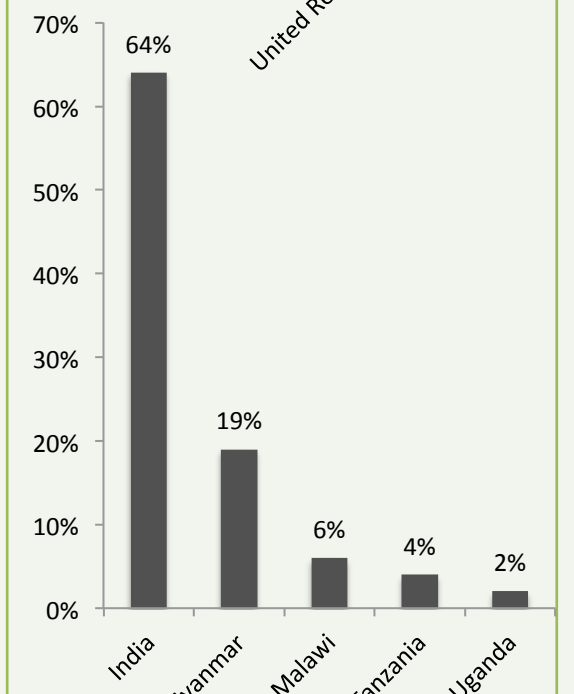

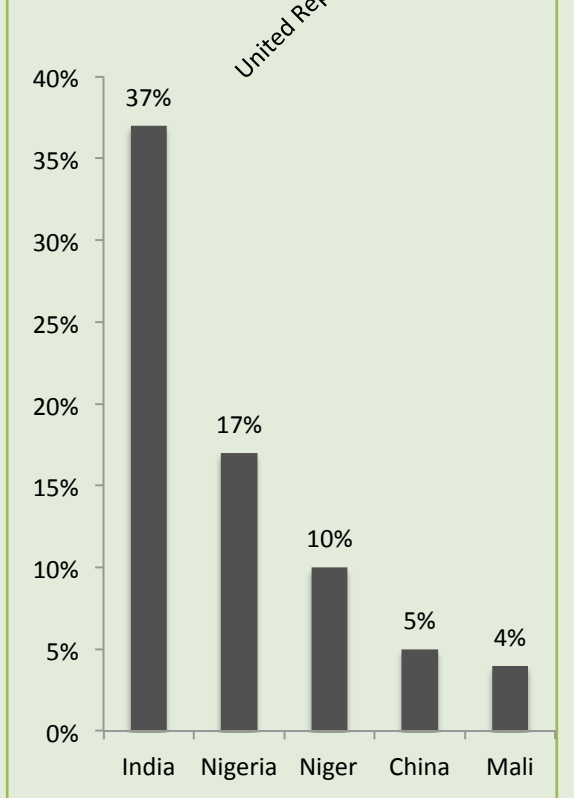

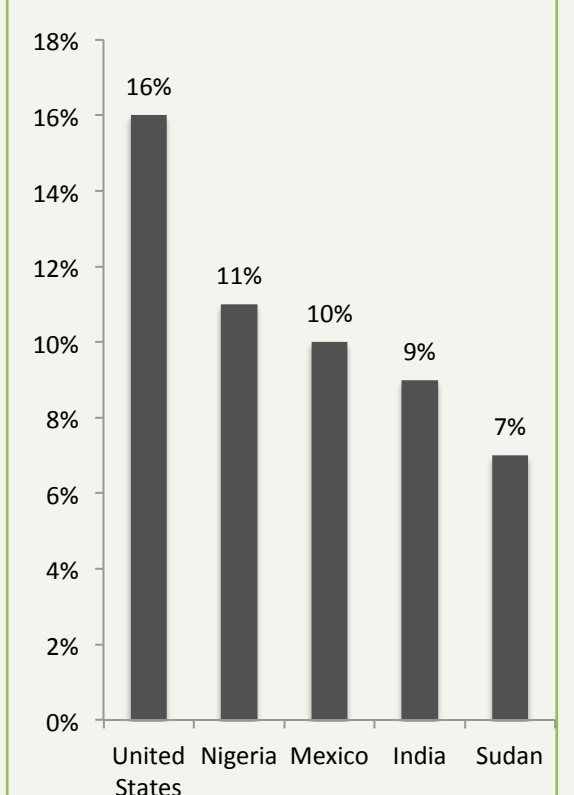

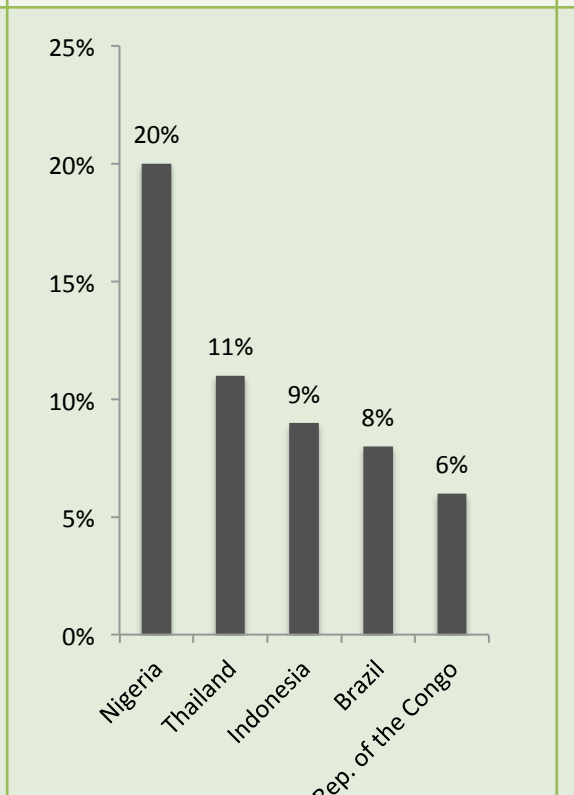

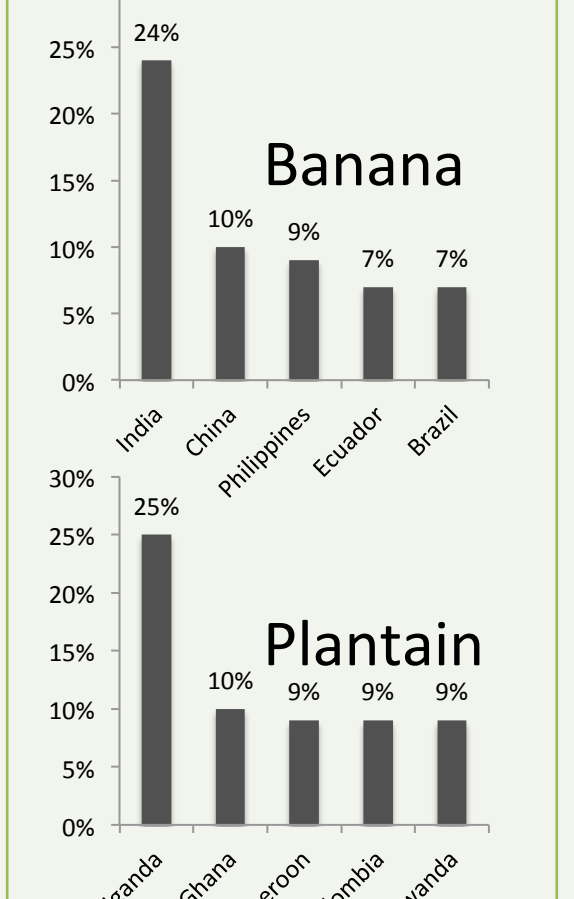
To feed the projected world population in 2050, global food production will need to increase by 70%, and by 100% in developing countries (Bruinsma, 2009). To meet these goals, it is essential that new biotechnology available today be utilized not only for major crops like maize, rice, wheat, and soybean, but also in orphan crops (Table 1). These investments have the potential to maximize benefits in developing economies and contribute toward boosting yield to meet goals for 2050. Bruinsma (2009) estimated that arable land would expand globally by less than 5%, and that 90% of the growth in production (80% for developing countries) would have to result from higher yields and more intensive agriculture.

Biotechnology has already made strides in contributing toward obtaining breeding goals for orphan crops. The most utilized technologies employ techniques that utilize single nucleotide polymorphisms (SNP) and quantitative trait locus (QTL) mapping, which help to mark, select for, and breed for desired genes with marker assisted selection (MAS) and transgenics.

Scientists have just begun to apply these techniques to orphan crop research, with some success. The table to the right details several traits discovered, as well as those incorporated successfully into confined field trials. Still, even newer technologies will allow breeders to identify desired traits and quickly incorporate them into varieties, and they have made alterations increasingly inexpensive and efficient. Plant breeding has one of the highest rates of return among investments in agricultural research, and with new technologies, like RNAi, high-throughput sequencing and direct genome editing, efforts can focus with less expense on orphan crops to apply what we already know from major crops to improve these essential, alternative staples.



Notable Crops and Findings

Crop	Top 5 Producers (% of global production)	Desired Traits for Food Security	Confined Field Trials	Commercial-ized?
Cowpea 		<ul style="list-style-type: none">Resistance to post-flowering insects (pod borer, pod-sucking bugs)Resistance to fungal, bacterial, and viral diseasesResistance to nematodesHeat and drought tolerance	Nigeria, Burkina Faso, and Ghana: insect resistant cowpea	none
Pigeonpea 		<ul style="list-style-type: none">Resistance to pests (pod fly, pot borer)Resistance to disease (Phytophthora blight, wilt, sterility mosaic disease)Shortened maturityDwarfingDrought, salinity, and temperature tolerance	none	none
Millet 		<ul style="list-style-type: none">Drought tolerance at reproductive and grain filling stageSalinity and thermo toleranceIncreased Phosphorus efficiencyResistances to pests and diseases (downy mildew, smut, rust, blast, etgot)Biofortification in pearl millet (iron, zinc, protein, vitamin A)Maintained heterozygosity through apomixis	none	none
Sorghum 		<ul style="list-style-type: none">Resistance to diseases (leaf blight, downy mildew, rust)Resistance to pests (shoot fly, spotted stem borer, midge, head bug)Resistance to StrigaBiofortification (protein, vitamin A, iron, zinc)Drought, aluminum toxicity, salt, and cold toleranceMaintained heterozygosity through apomixis	Nigeria, Kenya, South Africa, and Burkina Faso: Nutrient enhancement (vitamin A, zinc, iron).	none
Cassava 		<ul style="list-style-type: none">Increased drought toleranceDelayed postharvest physiological deteriorationPest (mealybug, cassava green mite, burrower bugs, thrips) resistanceViral resistance (cassava mosaic disease, cassava brown streak virus, bacterial blight),Biofortification (vitamin A, protein)	Kenya: Resistance to cassava mosaic disease Uganda: Resistance to cassava mosaic disease and cassava brown streak virus South Africa: starch enhanced (greenhouse trial) Nigeria: Nutrient enhancement (vitamin A, zinc, iron, protein)	none
Banana/ Plantain 		<ul style="list-style-type: none">Biofortification (vitamin A)Pest resistance (banana weevil)Disease resistance (black sigatoka, Xanthomonas & Fusarium wilt)Nematode resistanceDrought and thermo tolerance	Uganda: Black sigatoka resistance and vitamin A Egypt: Biofortified banana with viral resistance	none

Status of Biosafety Regulation in Africa

Thus far, commercialized genetically engineered (GE) foods in Africa include maize, cotton, and soybean. Cotton is commercialized in Burkina Faso and Sudan, maize in Egypt, and all three are commercially available in South Africa (ISAAA, 2012).

Although GE orphan crops have yet to reach commercialization, research is gaining momentum toward establishing additional confined field trials in countries where trials have yet to occur, which can aid help to nurture wider acceptance of GE orphan crops and encourage the creation of legislation that manages commercialization and dissemination.

Relevance

Major goals for most crops generally include selection for traits that increase nutrition as well as resistances to abiotic and biotic stress. Goals for orphan crop breeding even extend toward eventually suiting individual varieties to fit targeted farm systems and environments, preserving biodiversity. Ultimately, increasing crop yields and spurring distribution will be one of the most efficient ways to sustainably boost incomes or nutritional security for resource poor farmers in regions affected by highly variable yields, consistently low yields, or vulnerable to climate change.

Conclusion

In Africa, major crop staples (maize, wheat, and rice) accounted for barely 12.7 percent of the value of African crop production between 2008 and 2010 (Naylor, 2014); improvements to the orphan crops that compose the large majority of what is produced can be pivotal to the overall economic growth and the well-being of the poorest people in these regions. Ultimately, crop improvements should stimulate agricultural economies in these regions, alleviate hunger, create employment associated with these crops, reduce vulnerability, mechanize production, allow families to increase expenditures on other basic needs such as education and sanitation utilities, and contribute toward feeding the projected population growth in regions where these crops are cultivated.

Future Steps

1. Examine political constraints to commercialization.
2. Document progress of each crop per country as growth continues.
3. Assess acceptability of crops upon dissemination, analyze real impact on security.

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