Stone Fenton
The Taft School
Watertown, CT

Kenya, Factor 1: Utilizing plants to increase and improve crop yield and nutrition

Eighty percent of East Africans depend on agriculture for their livelihood, yet one third of the population suffers from malnutrition. Kenya and its East African neighbors (Tanzania, Uganda, Rwanda and Ethiopia) rely on the nourishing, but low-yielding, disease-prone potato for food security. A new, non-GMO, genetic breakthrough by a tiny Dutch company can pave the way to improved East African nutrition, increased farm income, reduced pesticide use and reduced food waste due to rot and disease.

The nutritious potato – rich in low-fat carbohydrates, high-quality proteins, vitamin C and potassium – is a major food crop in East Africa, grown widely by farmers in East African highlands. Potato is Kenya's second food crop after maize. Despite ideal growing conditions for potato – broad, fertile highlands, temperate climate and largely dependable rains – yields range far below attainable yields and the global average. Kenya's production is less than 10 tonnes per hectare while the National Potato Council of Kenya (NPCK) states that 40 tonnes per hectare should be achievable. Low yields prevent the potato from becoming a major cash crop for East Africa. Potato farming presents significant challenges:

- Low Yield – Due to the potato's genetic complexity, potato seeds produce unreliable results and are usually considered useless for planting. Instead, a portion of last year's crop are replanted to create new potato plants. Potatoes saved for replanting are called seed potatoes or planting tubers. Using a portion of the crop for replanting is one factor that significantly reduces yield.

- Systematic Waste – Planting tubers are exposed to rot, theft, disease and consumption by local rodents and insects as they wait for the next planting cycle. Substandard storage facilities compound the problem. "Usually the harvested crop is kept in piles on the floor or in bags. These conditions favor infection with pathogens that can easily spread and grow at these conditions. This results in a reduction of tuber quality and often complete rotting of tubers that are kept as starting material for next season."

- Disease – Planting tubers transmit disease to their offspring, whereas seeds do not. Potato disease is reported to cause around €10bn in damage to potato stocks worldwide every year, despite the intensive use of pesticides. A study found that virtually all East African seed potatoes were infected with a virus. Diseases that most seriously impact East African potato production include:
    - Potato Late Blight (caused by Phytophthora infestans)
    - Bacterial wilt (caused by Clavibacter michiganensis, Ralstonia solanacearum, Pseudomonas solanacearum)
    - Viruses (primarily Potato Virus Y (PVY))

- Heavy Pesticide Use – Potato plants are vulnerable to disease, requiring heavy pesticide use to combat late blight. Diseased tubers are often used for next year's planting, perpetuating the need for pesticide.

My proposal recommends establishing test fields in Kenya for a new potato breeding program using the best-adapted local varieties. (The program could be expanded to include Tanzania, Uganda, Rwanda and Ethiopia as well.)

A small Dutch company, Solynta, has developed (and patented) non-GMO, diploid, homozygous (rather than tetraploid, heterozygous) potato plants which can be used to produce reliable seed with genetically reliable characteristics. While still in its infancy, I believe this genetic breakthrough will revolutionize potato farming, bringing enormous benefits to farmers worldwide. Gains will be particularly pronounced in East Africa where potato farmers struggle with thin margins, poor storage facilities and disease.

New, Non-GMO Genetic Innovation

Cultivated potato plants are tetraploids which means they have four sets of chromosomes in their cell nucleus. Many organisms (including humans) are diploid, meaning they have two sets of chromosomes - one set inherited from each parent.

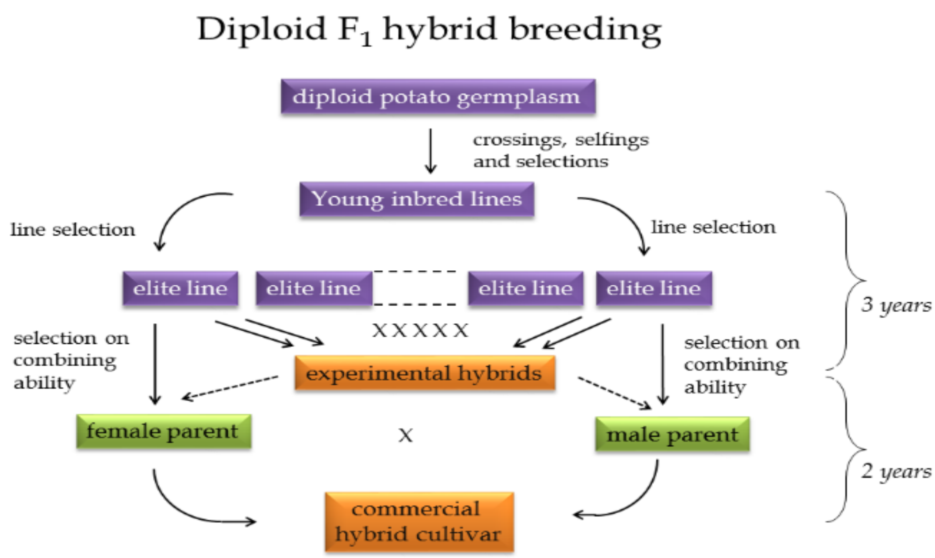
The potato is also genetically heterozygous, meaning the genes on its chromosomes pairs are different, a characteristic that results in its extreme genetic diversity and unpredictability for breeding. If both of the two gametes (sex cells) that fuse during fertilization carry the *same* form of the gene for a specific trait, the organism is said to be homozygous for that trait. Homozygotes, organisms with identical pairs of genes (or alleles) for specific traits, produce predictable offspring.

Lastly, a potato genome has over 30,000 genes. By comparison, the human genome has an estimated 20,000-25,000 genes. When one heterozygote, tetraploid, potato plant pollinates another heterozygote, tetraploid, potato plant, the seeds that are produced contain genetic characteristics that vary quite widely – too unpredictably for farming. Farmers know that even if last year's crop produced an abundant, hearty, good-tasting crop, resistant to local blights, the seeds from that crop could very well produce a thin crop of smaller, misshapen potatoes subject to disease or shorter shelf-life.

To circumvent the genetic unpredictability of potato seeds produced by their heterozygote, tetraploid parents, farmers have used vegetative cloning for thousands of years to produce next year's crop. When a farmer notices that a particularly favorable genetic trait has manifested in the crop (eg: resistance to local insects or disease), rather than eat or sell the fruits of his/her labor, farmers and hungry families are supposed to store their 'best specimen' potatoes to use for next year's planting. The new potato plant will be a clone of its parent. Vegetative cloning is a good way to insure a genetically reliable crop, but as mentioned earlier, dependency on last year's seed tubers presents a myriad of other headaches for farmers.

Controlled potato breeding and genetically reliable seeds have been an elusive dream, until now. Severe inbreeding depression and self-incompatibility (SI) were thought to make the development of a homogenous, diploid potato plant impossible. Solynta has overcome these hurdles using backcrossing and selfing to produce homozygous, inbred parent lines. These homozygous parents then produced diploid hybrids. The traits of the parent are gradually enhanced by crossing and selection. Experimental F1 hybrids can then be field tested to assess their performance and choose varieties for commercialization.

Solynta's new technology does not use genetically engineered or genetically modified organisms (GMOs). Rather it uses quite traditional breeding techniques which until now, have been impossible due to the genetically complex potato.



Source: Solynta

Immediate impact of Solynta's genetically reliable breeding will be the ability to use genetically reliable seeds for planting. Eliminating the myriad of problems seed tubers present will have significant, immediate benefits for East African farmers.

- Increased crop yield

  A farmer's entire crop (including 'best specimen' seed potatoes) can be sold or consumed.

- Dramatically reduced storage and transportation costs

  Seeds can be easily transported and stored. To plant one hectare, a small 25-gram bag of seeds is needed rather than 2,500 kilograms of seed potatoes.

- Reduced waste

  It will no longer be necessary to store seed potatoes until next planting cycle. Tuber rot, theft, disease and consumption by local rodents/ insects will no longer be a concern.

- Reduced use of pesticide

  Seeds are devoid of any pathogen and do not transmit disease to offspring plants (as seed tubers do).

Longer-term benefits of breeding diploid, homozygous potato plants will center on the ability to isolate certain desirable alleles. This, in turn, will solve many important East African economic and societal issues.

- Rapid Introduction of Better Potato Varieties

  Each growing season, new experimental hybrids can be tested in local Kenyan fields. Cultivars most optimally acclimated to local needs can be identified. New traits can be introduced via marker assisted selection.
  Tailor-made varieties with new resistances and other desired traits can again be tested in local Kenyan fields – each new generation dedicated to growing in East African environments.

  Because seeds are produced at high volumes in one growing season (one plant can produce about 25 million seeds in a year) there will be plenty of seeds with a particular desired trait for next year's crop.

- A Cure for Late Blight / A return to Organic Farming

  Phytophthora infestans cause Late Blight – a disease of potato foliage, stems and tubers. Potato blight caused the Irish Potato Famine in 1845-49 which caused over a million people to starve to death and forced another two million to emigrate. Today, Phytophthora infestans remains a major, expensive problem for potato farmers resulting in lost production estimated at billions of dollars worldwide.

  Solynta's breeders were recently able to cross-breed multiple resistance genes against Phytophthora infestans into potato plants. Identifying resistance genes, producing seeds and replanting these seeds to observe offspring results took under two years. In Solynta's test field in Wageningen, The Netherlands, healthy potato plants bred with two resistance genes show no sign of blight, while plants bred with a single resistance gene exhibit minor signs of infection.

  Until now, farmers have had only one option to save their crop when signs of infection become evident – spray heavily and frequently with a chemical pesticide. Introducing varieties suitable for organic farming, complete with natural protections against Phytophthora, will have significant environmental benefits for our soil and water.

  Solynta's success in cross-breeding multiple resistance genes against late blight into potato plants can be the first of many local disease-immunity successes.

- A new Cash Crop / An End to Poverty

  The creation of a high-producing, disease-resistant, better-tasting, nutrition-enhanced, hearty, super potato that thrives in local growing conditions would mean the birth of a new East African cash crop.

  The 800,000 Kenyan potato farmers and 2.7 million Kenyan's employed along potato marketing channels will experience increased incomes and may be lifted from poverty.

- An End to Hunger and Food Insecurity

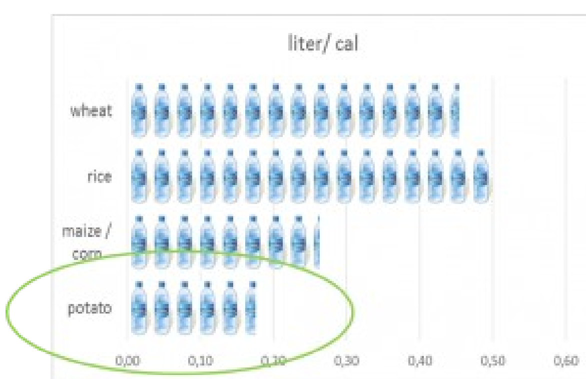
  According to the FAO, "The potato produces more nutritious food more quickly, on less land, and in harsher climates than any other major crop – up to 85 percent of the plant is edible human food, compared to around 50% in cereals." Solynta believes it can more than double the yield in developing countries, helping to significantly reduce hunger.

- Improved Nutrition

  Not only will there be more food, there will be better food. In addition to hardiness, resistance to disease and increased yield, improved nutritional value will be a principal breeding objective. The FAO reports that, "Potatoes are rich in carbohydrates, making them a good source of energy. They have the highest protein content (around 2.1 percent on a fresh weight basis) in the family of root and tuber crops, and protein of a fairly high quality, with an amino-acid pattern that is well matched to human requirements. They are also very rich in vitamin C – a single medium-sized potato contains about half the recommended daily intake – and contain a fifth of the recommended daily value of potassium." Solynta believes it is now able to, "specially and accurately breed varieties with improved nutritional value traits like (beta) carotene or vitamins and trace elements…which will contribute to an easy, healthy diet."

- Cleaner Water, Soil and Air

  Water: Agriculture consumes more than 80% of total available freshwater in Africa. Potatoes produce more dietary energy from the same amount of water than wheat, rice or corn. An increased consumer interest on nutritious, water-friendly potatoes could alleviate pressure on water resources.



Source: Solynta

Soil (and water): By breeding natural resistances into the crop there will be a significant reduction of pesticide use (Solynta estimates 60% less use) and therefore limit the runoff saturation of pesticides in farming soils and water systems.

Air: Small seed bags are logistically much easier to store and transport than bulky, perishable seed tubers. Seeds do not require refrigeration during transport in hot African climates. Less fossil-fuels are required to relocate seeds than commercial planting tubers.

The manufacture of pesticides also contributes to greenhouse gases.

Conclusion

With the ability to significantly improve the potato – Kenya's second most important food crop and the world's largest non-grain food crop – I believe we can end hunger, malnutrition and poverty in Kenya, all of East Africa – and ultimately, the world.

The genetically improved super-potato will feed the people of hungry nations while simultaneously improving our water, soil and air through reduced pesticide use, and reduced waste due to spoilage while in storage.

References

Berkeley College EvoLibrary, Your One-Stop Source for Information on Evolution. 2018. "Understanding Evolution." https://evolution.berkeley.edu/evolibrary/article/conservation_03, 2018.

Biology Online. 2018. Definition. www.biology-online.org/dictionary/Backcross. www.biology-online.org/dictionary/Homozygote.

Cornell University Department of Plant Pathology. 2018. 'Managing Potato Virus Y in Seed Potato Production.' www.potatovirus.com/index.cfm/page/PVYinfo.htm.

East African Community, 2018. "One People, One Destiny; Agriculture and Food Security" www.eac.int/agriculture, 2018.

Food and Agriculture Organization of the United Nations, 2016. "Water Withdraw Ratios by Continent", www.fao.org/nr/water/aquastat/countries_regions/profile_segments/africa-WU_eng.stm.

Food and Agriculture Organization of the United Nations. 2008. "International Year of the Potato." www.fao.org/potato-2008/en/aboutiyp/index.html

Food Valley Society. August 22, 2017. "Exploring the potential of hybrid potato cultivars in East Africa" www.foodvalleysociety.com/exploring-potential-hybrid-potato-cultivars-east-africa

Gildemacher, P.R., Demo, P., Barker, I., Kaguongo, W., Woldegiorgis, GT., Wagoire,W.W., Wakahiu, M. Leeuwis, C. and Struik, P.C., A Description of Seed Potato Systems in Kenya, Uganda and Ethiopia, American Journal of Potato Research 86, 373-382, 2009.

GMWatch. News and comment on genetically modified foods and their associated pesticides. August 31, 2017. www.gmwatch.org/en/news/latest-news/17821-solynta-develops-non-gmo-late-blight-resistant-potato-varieties.

International Potato Centre, 2018. "Seed Potato for Africa," https://cipotato.org/programs/seed-potato-for-africa. https://cipotato.org/crops/potato.

Kenya Agricultural and Livestock Research Organization. Demand Driven Research for Food Security and Income Generation. 2018. www.kalro.org/about_us.

Kenya Plant Health Inspectorate Services (KEPHIS). 2018. www.kephis.org/.

Lindhout, P, and de Vries, Danial, D, "The Potential of Hybrid Potato Cultivars in East Africa", Open Agriculture, Vol 1, Issue 1, December, 2016.

Modern Ghana, "Experiment in Congo By Dutch Company Solynta Proves Extraordinarily Successful". March 10, 2017. www.modernghana.com/news/760573/experiment-in-congo-by-dutch-company-solynta-proves-extraord.html.

National Potato Council of Kenya. "Potato Industry in Kenya." 2018. http://npck.org/.

NSF Potato Genome Project, Berkeley College. 2018. Potato Biology. Heterozygosity. http://potatogenome.berkeley.edu/nsf5/potato_biology/heterozygosity.php.

Potato Pro. August 22, 2017. "Solynta develops a blight resistant potato variety (non-GMO)" www.potatopro.com/news/2017/solynta-develops-blight-resistant-potato-variety-non-gmo.

Potato Pro. August 23, 2017. "Solynta's Revolutionary Hybrid Breeding Technology Protects Potato from Late Blight by Multi-Resistance" www.potatopro.com/news/2017/solyntas-revolutionary-hybrid-breeding-technology-protects-potato-late-blight-multi.

ScienceDaily. Jul 12, 2017. Human Genome. www.sciencedaily.com/terms/human_genome.htm.

Solynta Hybrid Potato Breeding, Refresher on Genetics. 2018. http://solynta.com/index.php/refresher-on-genetics/. http://solynta.com/index.php/hybrid-breeding-how-does-it-work/.

The History Learning Site. "The Great Famine of 1845". 2018. http://www.historylearningsite.co.uk/ireland-1845-to-1922/the-great-famine-of-1845/.

University of California, Division of Agriculture and Natural Resources, Seed Biotechnology Center, Germplasm, 2018. http://sbc.ucdavis.edu/About_US/Seed_Biotechnologies/Germplasm/, 2018.