Addressing Global Food Insecurity for the Present and the Future

KeyGene leads the way

Dr. Peter van Dijk & Dr. Stephen E. Schauer

The Challenge of World Hunger

Mankind is facing an enormous challenge of food insecurity. By the year 2050, the population of the world is projected to increase by 35% to a whopping 9 billion; and an almost doubling of global food production is needed to feed the planet [1]. This additional food for humans and farm animals has to come from the existing land, through maximization of genetic potential and relatively quickly. This demand for unprecedented productivity in agriculture needs to be realized in the presence of growing challenges of climate change, shortsighted land-use practices and increasing cost of agriculture despite the rate of improved adoption of technology in crop breeding. Recent advances in our understanding of genes and genomes combined with development of novel tools in biotechnology will play a vital role in accelerating efforts in plant breeding; however, current approaches are inherently slow, costly, and cannot capture all beneficial gene interactions. More strikingly, the projections by Ray and colleagues [2] indicate that the current approaches will be unable to produce the needed increase. In light of this, rather grim outlook, a radical revolution in plant breeding is needed to be able to achieve the level of productivity needed to address global food insecurity. KeyGene is igniting this revolution by defining a path forward to boost global crop yields through an asexual breeding approach called apomixis.

Apomixis Breeding: A Disruptive Innovation

Apomixis is a mode of seed production in plants by asexual means. The apomictic seeds produced as a result of this relatively rare biological phenomenon (seen in ~250 wild plants, with only 1 in 1,000 species being apomictic) are clones of the mother plant. Successful introduction of apomixis into crops would not only allow for clonal production of seeds: perfect genetic copies of the mother plant, but also would fundamentally alter the current plant breeding paradigm through the introduction of the game-changing apomixis breeding. With apomixis breeding, pollen of apomicts could transmit apomixis inducing genes in crosses with sexual plants [3]. Seeds from the selected apomictic plant with a superior phenotype would be used directly for replicated field trials and ultimately released as a new cultivar.

Currently, the development of a completely new cultivar of an annual crop takes at least 7-12 years to bring to the market, with costs in millions of dollars [4]. With apomixis breeding, this process would be reduced to only a few years, significantly reducing the costs to generate a cultivar. Moreover, the bulk seed production of established apomictic varieties will be logistically less complicated than that of present-day sexual F1 hybrids. The reduction in breeding and seed production costs would allow the development of more cultivars that are better adapted to local environments, reducing the problems associated with monocultures of a few cultivars. If broadly applied, apomictic breeding would benefit breeding operations of all sizes: smaller breeders would have broader access to the market due to the ability to efficiently bulk up their cultivar production, while larger breeders would be enabled to economically expand their product portfolio with more specialty varieties. Clearly, realization of apomixis would be a disruptive innovation.

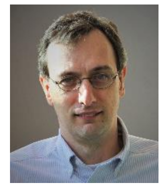
Apomixis Is Within Reach

Over the last three decades, efforts towards understanding the molecular basis of apomixis have been limited; however, the significance of its impact on humans around the globe continues to keep such efforts alive. Apomixis is a complex problem that requires an in-depth understanding of plant genetics, physiology, and reproductive biology. Further, an array of tools and technologies are also essential for rapid assay, analyses and molecular breeding of positive outcomes. KeyGene is a unique company in the world with a legacy of over 25 years of plant breeding expertise, state of the art technologies and a penchant for crop innovation; who has continued its relentless pursuit to harness apomixis.

KeyGene is a leader in crop innovation and a powerhouse of technological innovation and translation in the global plant breeding industry. Over the years, KeyGene has made significant contributions to global agriculture through the introduction of multiple impactful technologies like Sequence-Based

About the authors

Dr. Peter van Dijk, senior plant reproductive biologist at KeyGene, with specialization in reproductive traits in plants.



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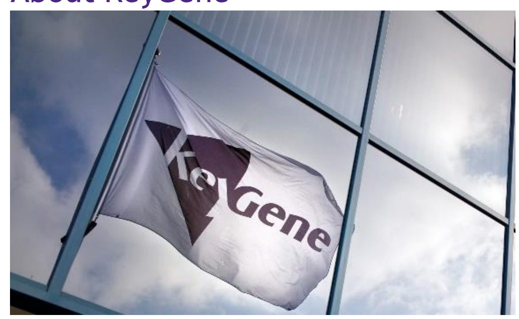
About KeyGene



KeyGene, The Crop Innovation Company

KeyGene is a privately owned Ag Biotech company with a primary focus on crop innovation. KeyGene's approach is to enable molecular genetics for the future of global agriculture. KeyGene supports its strategic partners with cutting edge breeding technologies, bioinformatics and plant-based trait platforms, with more than 135 employees from all over the world. KeyGene has sites in Wageningen, the Netherlands and in Rockville, USA

Apomictic & non-apomictic

An apomictic dandelion (flowers with seeds; left) and a non-apomictic dandelion (flowers without seeds; right).

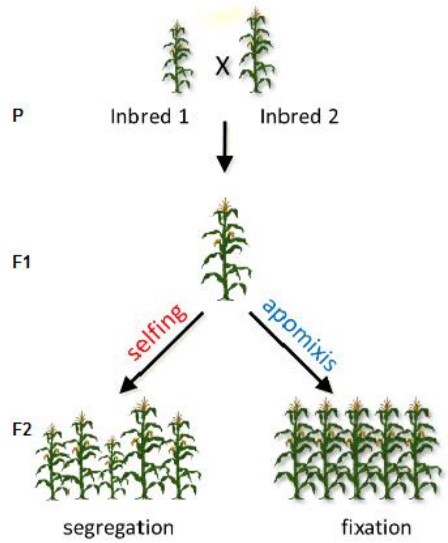
Genotyping (SBG), KeyPoint® Mutation Breeding, KeyBase® precision genome editing, KeyGene® SNPselect, and digital phenotyping; all of which have led to accelerated innovation and expedited breeding of market-relevant varieties for its partners. Dr. Peter van Dijk, senior plant reproductive biologist at KeyGene, is on the forefront of the apomixis revolution and leading the quest for a solution for world hunger.

It is now recognized that apomixis is controlled by one or more dominant loci that suppress the process of normal sexual reproduction [5]. This suggests that introduction of apomixis in crops may not be as complicated as previously thought. At the prestigious event honoring the 150th anniversary of the publication of Gregor Mendel's work on genetics, Dr. van Dijk discussed recent advances, including the successful cloning of one of the first apomixis genes in a naturally apomictic species, the common dandelion. KeyGene's findings were further supported by independent work in fountain grass, *Pennisetum squamulatum*[6]. Proof of concept studies to transfer apomixis in crop plants of global agricultural relevance are underway. Based on recent advances in the field and in recognition of KeyGene's expertise in apomixis, Dr. van Dijk's team was invited to present apomixis breeding to a wider audience by the journal Current Biology [7]. Here, the authors lay out a case for the introduction of apomixis in crop plants, which would not only reduce seed production costs, but also significantly expedite the breeding phase of cultivars.

The Soybean Game Changer

Soybean is the most important protein and oil crop, with a worldwide production in 2014 of 308-million-ton seed on land acreage of 117 million hectares [8]. The currently cultivated inbred lines do not take advantage of the potential for high yields through F1 hybrids [9].

Unlike corn, the benefits of hybrid soybean varieties cannot be exploited since an economical method for the large-scale cross-pollination, essential for production of F1 hybrid seeds, is currently non-existent. The introduction of apomixis into soybean stands to dramatically change the situation: a single cross pollination using apomictic pollen would be sufficient to produce an apomictic F1 hybrid. This hybrid would have the benefits of both heterosis as well as direct heritability from one generation to the next. As a result of being able to make exact copies of themselves, apomictic F1 hybrids



Apomictic reproduction conserves heterosis, pronounced vigor seen in F1 hybrids, when compared to their inbred parents. With sexual reproduction (selfing), the superior phenotype breaks down in the next generation due to segregation.

allow the commercial scale-up of seed production needed for global release of new cultivars within unprecedented timelines. This reduced cost of producing cultivars allows breeding programs to increase the number of cultivars generated and tested in the field, thereby facilitating development of specialized cultivars suited to specific environmental conditions. Further, the ability to make perfect genetic copies of such cultivars through apomixis breeding ensures easy dissemination to specific geographies and for local reproduction of a clonal population. Thus, while not only being economically beneficial to plant breeders in terms of lower production costs, an asexual apomictic breeding revolution could supercharge the efforts needed to increase food production while mitigating the production losses due to climate change. The imminent possibility will have consequences not only in production agriculture, but also on breeder's rights, regulatory requirements, the seed industry and the global economy.

The Renaissance in Plant Breeding

Clearly, significant breakthroughs in apomixis have been long overdue. KeyGene's discovery of genes central to apomixis and the immense impact of apomixis in plant breeding can be highlighted by drawing analogy to the game-changing influence of the printing press at the end of the Middle Ages. Just like the printing press, which allowed exponential dissemination of information that ultimately spurred the Renaissance [9], apomixis in crop plants has the potential to revolutionize breeding by generating unlimited numbers of cultivars at a fraction of current costs. Whereas the printing press generated abundant food for thought, the apomixis breeding will produce abundant food for the needs of a growing global population.

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