

FACTSHEET: MANIPULATION TO IMPROVE SUSTAINABILITY OF BIOMASS PRODUCTION

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The plant **microbiome** is the associated environment surrounding the plant, made up of various commensal, symbiotic, or parasitic microorganisms; the naturally occurring biological, chemical, and physical properties of the plant, soil, water, and air all impact the growth and decomposition of the plant.

Focus on methods to increase output and the economic viability of certain biomasses has shifted from a gene-manipulation approach to include a microbiome-manipulation approach. In other words, to increase yield, what **biological, chemical, and physical factors should plants be exposed to?**

Genetic engineering of plants aimed to make crops more resistant to disease has shown much promise and potential,¹ but may have also resulted in unintended consequences (e.g., the increase use of insecticides).

On the other hand, **the introduction of beneficial microbes into a plant's roots or soil can positively affect its growth in a less invasive manner by²:**

1. Breaking down nearby litter
2. Cycling nutrients
3. Synthesizing vitamins, enzymes, hormones
4. Altering soil structure
5. Decomposing weeds
6. Feeding on parasites and suppressing plant disease

Researchers employ DNA sequencing on samples of plants and the soil the plants are grown to assess its composition and abundance of microbes, what these microbes are capable of, and how these microbes function together.³ Most importantly, interactions in context are considered; certain beneficial bacterial relations, for example, may differ outside of the specific plant microbiome and may be malicious to other plants.

WHAT ROLE DOES MICROBIOME MANIPULATION PLAY?

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Uncontrollable environmental factors such as sunlight exposure and temperature may be difficult to promote or repress when trying to increase plant growth and yield.

In the wake of population growth and climate change, microbiomes serve as a means to add more value to crops and increase productivity in the agriculture sector.

Food security has been better stabilized with genetic plant breeding technology has so far only proved beneficial to specific crops. Microbiomes may be the tool to diversifying and increasing plant yield.

The world population as of December 2017 was estimated to have reached **7.6 billion** people, and by the year 2100 is expected to reach **11.2 billion** people.⁴

With growing energy and food needs, microbiome manipulation may be the answer to increase plant health and meet future demands.



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¹ Barrows, G., Sexton, S., & Zilberman, D. (2014). Agricultural biotechnology: the promise and prospects of genetically modified crops. *Journal of Economic Perspectives*, 28(1), 99-120.

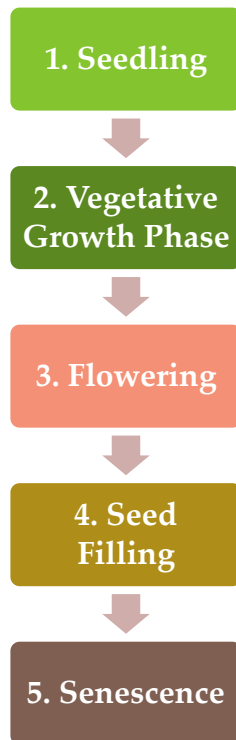
² Hochman, Gal. *The Bioeconomy: Technology and Policy Path Forward*. 2016.

³ Gopal, Murali, and Alka Gupta. "Microbiome Selection Could Spur Next-Generation Plant Breeding Strategies." *Frontiers in Microbiology*, Frontiers Media S.A. , 7 Dec. 2016, doi.org/10.3389/fmicb.2016.01971.

⁴ "World Population Prospects - Population Division." *United Nations*, United Nations, esa.un.org/unpd/wpp/DataQuery/.

PLANT MICROBIOMES

Stages of Growth: Dr. Stephen Moose, of the University of Illinois Urbana-Champaign, emphasizes in his research that to increase plant output and quality, fundamentally you must elongate stages of plant growth (pictured below).⁵



To optimize protein and oil output and increase biomass, sugar and starch in the plants, the plant must remain in its vegetative growth phase for a longer time. Guiding the plant to do so will make the biomass more economically viable by increasing content of the plant that may be harnessed for biofuels and bioproducts. Moose, likewise, has also explored elongating other phases: shoot maturation, tillering, flowering time, senescence, and harvest index, which is used to measure reproductive efficiency in plants.



Nitrogen Utilization: Plant productivity is proven to increase when plants, specifically corn, are supplemented with nitrates.⁶ Improving nitrogen utilization across the board of vegetation will altogether improve the sustainability of these crops, whilst also reducing environmental impacts to soil and stabilizing growth of surrounding vegetation. Asparagine-cycling gene research proves useful in untapping stored nitrogen in chloroplasts, where 80% of plant nitrogen in the leaf is kept, to use to increase plant growth.⁷

Stem Oil: Studies to increase oil concentration, by manipulating plants to accumulate oil in its stem, increases the biomass value of the plant stem. For this reason, stalky crops like sorghum, corn, sugarcane, and tall grasses are experimented on. Genetic engineering initiatives in plants for biofuel production offer promising results for increased breeding and yield.

Biofertilizer: In order to ensure the up-to-standard quality, productivity, and health of the plant, some researchers are opting for biofertilizers to influence growth. The eco-friendly fertilizer is packed full of beneficial microorganisms to better enhance the soil; it serves to assist in nitrogen-fixation, growth stimulation, soil fertility restoration, and soil-borne disease protection. Not only do biofertilizers help increase crop yield by 20-30%, but they also diminish chemical use of nitrogen and phosphorus.^{8,9} Bio-compost similarly offers can assist in soil rejuvenation.

In field trials, biofertilizers have proven to increase grain yield between 9.5% and 14%. In other words, a normal, more expensive fertilizer used to farm an acre of land could be substituted with biofertilizer and keep the same yield at a lower cost. Additionally, farmers face nonmonetary costs of using regular chemical fertilizers on their land by spreading the pesticidal chemicals; these chemicals then seep into the ground and into nearby ground water sources and streams, impacting wildlife and naturally-balanced ecosystems.

⁶ Moose, Stephen, and John Dudley. *Maize Selection Passes the Century Mark: a Unique Resource for 21st Century Genomics*. University of Illinois, 2004, *Maize Selection Passes the Century Mark: a Unique Resource for 21st Century Genomics*, dx.doi.org/10.1016/j.tplants.2004.05.005; Moose, S. P., & Mumm, R. H. (2008). Molecular plant breeding as the foundation for 21st century crop improvement. *Plant physiology*, 147(3), 969-977.

⁷ Postin, Cody Keith. *Effect of Nitrogen Form and Genetic Variations of the Asparagine-Cycling Pathway on Maize Ear Growth*. University of Illinois, 2014, *Effect of Nitrogen Form and Genetic Variations of the Asparagine-Cycling Pathway on Maize Ear Growth*, www.ideals.illinois.edu/bitstream/handle/2142/49781/Cody_Postin.pdf?sequence=1&isAllowed=y.

⁸ "2012 Census Highlights." *USDA - NASS, Census of Agriculture*, USDA, 16 June 2017, www.agcensus.usda.gov/Publications/2012/Online_Resources/Highlights/Farm_Economics/.

⁹ Nehring, Richard. "Fertilizer Use and Price." *USDA ERS - Fertilizer Use and Price*, USDA, 12 Oct. 2016, www.ers.usda.gov/data-products/fertilizer-use-and-price/fertilizer-use-and-price.

SWITCHGRASS

Perennial native grasses, especially warm season perennials, are being pushed by energy agencies for biofuel initiatives because of their adaptive characteristics.

Switchgrass holds the dominant ability to self-seed, grow, and produce under various weather conditions and soil and terrain types in the United States. Often the grass is grown on lands assigned as non-food crop lands.

Switchgrass requires low input and is resource efficient making it a majorly-viable bioenergy crop, with high economic return.

According to Iowa State University, in 2016 it was expected that switchgrass could be sold for \$70 per ton at dry weight. The net return in dollars per acre over the course of 10 years after field prep, planting, and the first year of growth, is steadily estimated at \$165.¹⁴

Ten years of productivity are expected after the first planting of switchgrass.

Corn and Soybean are two of the most abundant feedstock sources for biofuel. According to Iowa State University, from 2016 to 2017, of the projected 15,640 million bushels of corn in supply in the US a total of 13,905 million bushels are used for feed, ethanol, food and seed, and exports. Almost 40% of the used corn was used to produce biofuels.¹⁰ Similarly from 2016 to 2017, of the projected 4,389 million bushels of soybean in supply in the US a total of 3,784 million bushels are used for crush, seed, and exports. Almost 11% of the used soybean was used to produce biofuels.¹¹

The microbiome offers researchers the ability to alter characteristics of the phases of plant growth. In some strains of corn and soybean, for example, genetically altered seeds are incorporating pesticides. The implementation of these new seeds alters day-to-day production techniques and costs.¹² Since seeds are already pest resistant, excess capital is gained by farmers who no longer need to consider pest problems or preparations for lost crop due to pests.

Similar “new seed” technology can alter other farm practices like the use of regular fertilizers and timely harvesting. Now, fertilizers may be used on an as-needed basis as opposed to ritual every harvest season. Cost structures in corn and soybean and other crops may be altered due to the implementation of microbiome manipulation and genetic modification; microbes have the ability to change the physiology of a plant, which prospectively may enhance the crop to an extent where we can abolish the need for chemical fertilizer altogether.

What is ahead in the future? Microbiome manipulation can ensure that crops produce in changing climates, produce with less water, and produce in degraded soil; the key to reversing soil degradation is changing and promoting the health of the soil microbiome. As of 2016, 1.5 billion people globally must depend on degraded land for food or survival. If agricultural practices stay the same for the next 30 years, the UN predicts a 12 percent decline in global food production because of land degradation and an increase in loss of biodiversity and water scarcity, which may in turn lead to the displacement of millions of people.¹³

There is potential for nutrient restoration, ecosystem stabilization, and breeding incrementalism in plant microbiome manipulation technology. Despite information gaps, fundamental studies provide evidence of the beneficial impacts of microbiome-concentrated techniques that change plant functional traits like leaf nutrient levels and plant life longevity; this provides the world with a dependable method to grow certain crops and confident food and energy security.

¹⁰ Wisner, Robert. “Ethanol Usage Projections & Corn Balance Sheet.” *Agricultural Marketing Resource Center*, AGMRC, 21 Dec. 2015

¹¹ Wisner, Robert. “Biodiesel Usage Projections & Soybean Balance Sheet.” *Agricultural Marketing Resource Center*, AGMRC, 21 Dec. 2015.

¹² Duffy, Michael D. “The 2011 Costs of Crop Production.” *AgDM*, Iowa State University, Dec. 2010, www.extension.iastate.edu/agdm/articles/duffy/DuffyDec10.html.

¹³ “On Day to Combat Desertification, UN Calls for Action to Restore Land Resources.” *UN News Center*, United Nations, 17 June 2016, www.un.org/apps/news/story.asp?NewsID=54255#.WmomR6inHW.

¹⁴ Jacobs, Keri. “To Grow or Not to Grow: A Tool for Comparing Returns to Switchgrass for Bioenergy with Annual Crops and CRP To Grow or Not to Grow: A Tool for Comparing Returns to Switchgrass for Bioenergy with Annual Crops and CRP.” *AgDM*, Iowa State University, Jan. 2016, www.extension.iastate.edu/agdm/crops/pdf/a1-27.pdf.