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Genetic Engineering to Add Traits Not Natural to the Feedstock

On August 1, 2012, The National Petroleum Council (NPC) in approving its report, *Advancing Technology for America's Transportation Future*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Task Groups and/or Subgroups. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

Genetic Engineering to add traits not natural to the feedstock

By Tom Binder

Until the global population stabilizes sometime in the latter half of this century, there will be a need for deployment of more intensive agricultural practices on all arable land. As a counter point to this, there will be simultaneous pressure to implement long-term sustainability practices to protect ecosystems needed for genetic diversity and to ensure ongoing health of farmland. While these two pressures appear to be at loggerheads, this does not necessarily need to be the case. As an example, herbicide resistance has allowed increased production while at the same time making no-till methods more practical. Continued development of agronomic traits that provide more opportunities for integrated pest and weed management will be needed to stay ahead of the development of resistance in nature.

With increased demand for agricultural and forestry output , research that focuses on productivity gains and cultural practices to promote those gains (while protecting the environment) will need to be supported at higher levels by both government and industry. Technologies proven to increase production while decreasing inputs will need continued public support for rapid deployment and adoption. Traits, in addition to the herbicide resistance previously mentioned, that will have significant impact on production in the temperate agricultural regions present in North America should also be developed. Some of the traits relevant to yield improvements of both conventional and non-conventional crops are listed below:

1. Frost tolerance and the ability to germinate at colder temperatures. Traits such as this will allow longer growing seasons, faster canopy development before weeds compete for resources, and earlier maturation before the highest summer temperatures.
2. Drought and heat tolerances. These traits will enable photosynthesis and growth to continue during stresses from water deficits and high summer temperatures. Heat tolerance, both in daytime and nighttime, will be an increasingly important trait, depending on the pressures climate change brings to North American agricultural regions.
3. Water and nitrogen use efficiency. This is not only important in the development of primary crop traits but also in those of cover crops that will enhance moisture and nutrient retention outside of the primary crop cycle.
4. Salt water tolerance. Transfer of traits from salt-tolerant halophiles to agriculturally useful crops will allow for use of brackish water for irrigation and for the reclamation of agricultural land that has become too saline for continued use.
5. Perenniality for crops such as corn and wheat. While annual varieties have been easier to breed and develop, perennial varieties may require fewer inputs and become cost effective as our ability to use technology to breed novel forms of crops develops.
6. Nitrogen use efficiency or nitrogen fixation. The ability to scavenge more of the nitrogen that is available at lower levels in the soil will decrease the amount needed to be applied as fertilizer. Developing nitrogen fixation symbiosis systems could potentially reduce the need for fertilizer applications. These are complex systems to develop and manage but have large potential to

lower energy inputs in the form of synthetic nitrogen and to lower losses to the nations watersheds.

7. Plant-mediated and exogenous manipulation of rhizosphere microbial populations. Such traits would target increased mineral nutrient uptake; reduced insect, nematode, and disease pressure; root growth and morphology; and induction of systemic resistance.
8. Increased photosynthetic efficiency. Small increases in efficiency can have a large benefit since most crops are only between 1% to 3% efficient at using incident sunlight. Many sources of improvements are possible, ranging from eliminating feedback systems in crops that reduce photosynthesis to changing plant architecture and increasing the growing season.
9. Maintained photosynthetic efficiency during grain fill. This important physiological trait is termed "functional staygreen" and focuses on a specific, heritable trait that should improve yield. Extending grain fill or crop maturation could significantly increase yield.
10. Controlled senescence of energy crop biomass , both annual and perennial. Where crop residue and biomass crops are grown, the ability to get the mineral and nitrogen in the harvested biomass portion moved into the root and/or the portion of the plant that stays in the field will reduce both processing costs and the need for mineral fertilizer use
11. Development of traits that improve utility per unit dry matter. Included in this would be resistance to microbial and insect degradation of harvested grain in storage and production of higher value substrates for biological (e.g., nutrition, fermentation, high starch, high oil) or thermo-chemical (e.g., pyrolysis) processing applications.

While this list is not meant to be comprehensive, it does illuminate the potential extent to which an increased understanding of how nature has been able to adapt plants to every environment will help our agricultural and forestry industries develop crops for increased yields with less intensive inputs. Most of the solutions we will need are already out there in the biosphere; our job is to recognize and deploy them to meet a growing global demand.