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Short Communication

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with standardized appropriate parts, and with predictable and reliable expected functions [9].

Because the synthesis of most metabolic pathways such as the one for oil biosynthesis or for plant cell wall biosynthesis circuits are so large, scientists working on such synthetic biology also need to use the routine engineering techniques called"decoupling and abstraction"i.e. breaking of the whole circuits into smaller modules or pieces, and testing of each pieceprior to their assembly [2].

Like in engineering, the prefabricated parts such as DNA pieces must be combined following the engineering rules of "assembly standard" including speed, versatility, laboratory autonomy and full combinational potential where the parts can become interchangeable. Despite the above rules, the need for mathematical modeling of each piece of the circuits or each prefabricated part is important in order to assure the rationality of the designed genetic circuits [2].

Also, in an ideal 21st century a ordable manufacturing scenario, the pre-fabricated parts of any circuits should also be potentially used in di erent synthetic biology hosts such as di erent crops.

A very powerful DNA assembly system called "Golden Braid" has been used in plant synthetic biology research. is DNA assembly system contains DNA building modules (parts) to be used in di erent crop synthetic biology approaches, a system that can be optimized for many uses. e Golden Braid DNA assembly modules arealready commercially sold in form of a "tool kit" for their uses in plant synthetic biology research [1].

e authors team used the techniques of RNAi genetic engineering and produced a corn crop that its cell walls contains about 8% less lignin, and therefore not only its stover could be converted into fermentable sugars with less needs for pretreatment processes, but also the energy saved by plants by producing less lignin was shi ed to producing more cellulose resulting in more fermentable sugars [10,11] Using synthetic biology of corn crop, it might be possible to improve the systen by rst logically designing the circuits network, measuring the stability of its steady-state, modelling their behaviors, and nally assembling the system in form of genetic circuits with standardized appropriate parts, and with predictable and reliable expected functions. erefore the crop synthetic biology is much more complicated, but also more precise with better predictable results.

e author's team also produced a corn crop that its stover expresses all three microbial cellulase enzymes (endoglucanse, exoglucanase and beta-glucosidase) needed to convert the plant cellulose into fermentable sugars. is transgenic corn cropself-produces all of these three cellulases in its stover (not in owers, seeds or roots) and such stover could be converted into fermentable sugars without the needs for any externally applied microbial cellulases [12]. If the system was to be synthetically made using the technologies associated with synthetic biology, it should be possible to logically design circuits networks of crop cell walls consisting of cellulase genes, measure the stability of their steady-state, model their behaviors, and assemble the system in form of genetic circuits with standardized appropriate parts, and apply the system for production of a novel corn crop with predictable and reliable expected functions of self producing cellulases.

It might be also possible to combine both of the above examples to produce a bio energy crop with ideal cell walls that have high cellulose and hemicelluloses molecules; but with stronger but yet more bioprocessable lignin contents.

Plant synthetic biology can also include multiple genetic regulatory system designs [13], such as switches or promoters to turn on and o the genes as they are required [2].

Synthetic biology of *E.* -producing butanol by Michelle Wang's team is a great example of the potential of the powerful synthetic biology [14]. It is also encouraging to see the most recent advances in comprehensive DNA assembly framework developed for plant synthetic biology [1].

In using the plant synthetic biology, it is also possible to predict the directed evolution and use such predictions to design novelcrops similar to those selected in vivo for the best traits [15], or produce novel cereal crops that can x nitrogen, x carbon more e ciently with a much more e ective photosynthesis, produce and store more sugars, have water use e ciency, disease and pest resistance and more nutritious seeds and vegetative tissues.

Despite all of its prmisses that potentially can advance the foold and energy security and produce low-coss industrial products, there are multiple challenges associated with the application of the crop synthetic biology. e challenges are; (1) unavailability of most naturally existing biological genetic pathway systems and the ambiguity of the certain genes involved such as those in cell wall synthesis pathway [16] or plant fatty acid biosynthesis and assembly pathways for oil production [17], (2) limited and impeding ability to rationally designthelanguage of the plants genetic system [18,19] and its gene circuits for the nest predictable direct evolution, (3) the unpredictable evolution of the genes' regulatory sequences, and (4) the acceptance of synthetically produced crops by the public.

While more fundamental research is needed to reduce most of the above challenges, the author expects major public concerns on the applications of synthetic biology. However, such concerns would lessen as soon as the bene ts of synthetic biology become more obvious to the public. Public needs to become educated by social scientists and by the media on the most humanitarian bene ts of the system biology, such as the one developed for the creation of the award winning anti-malarial drug produced through synthetic microbes [20]. Such drug can save millions of human lives in the developing nation where malaria is the most cause death, especially in children.

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