Can cucumber breeding help break through a yield plateau?

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Improve Life.

Plant breeding background

- Stokes Seeds Ltd.,
  - fresh market field tomatoes
  - sweet and hot peppers
  - sweet corn
- Ridgetown,
  - processing tomatoes

I am a processing tomato breeder

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A CONNECTION BETWEEN PICKLES AND TOMATOES

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FARMING BACKGROUND – A LONG TIME AGO . . .

- Raised on a fruit and vegetable farm
  - Strawberries
  - Apples
  - Processing tomatoes
  - Sweet and hot peppers for pickling
  - Pickling cucumbers !!

My experience is from the late 1970s – pickling cucumber production has changed a lot since then.

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Can cucumber breeding help increase yields further?

- What traits are cucumber breeders working on?
- How might those traits help increase yields?
- Sometimes genetic traits alone are not enough
  - May need to adjust the entire production system in order to get the benefits
- Some traits may result in big gains, while others may result in incremental gains

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ACKNOWLEDGEMENTS

- Yiqun Weng, cucumber genetics, genomics and breeding
  - University of Wisconsin-Madison and USDA-ARS
  - Large and active research program with many publications
  - Much of the material I present will come from publications from his lab

- Additional material from other labs

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Cold tolerance – could we sow earlier, or preserve yield through a cool period?

- Cucumbers sensitive to low temperatures
  - Below 20°C day or 8°C night
  - Results in leaf yellowing, accelerated plant aging, reduced yield
- Low temperature sensitivity is influenced by many genes

- One region of chromosome 6 was discovered to have 2 genes, closely spaced, that explain 24 to 26% of the variation for cold tolerance (seedlings grown at 15-17°C for 2 weeks)

- Could we gain more if combined with other cold tolerance genes?

Dong, et al., 2019. Quantitative trait loci mapping and candidate gene analysis of low temperature tolerance in cucumber seedlings. Frontiers in Plant Science 10-2019: https://doi.org/10.3389/fpls.2019.01620

Genetic control of fruit size – can we improve uniformity of fruit size at harvest?

- Harvest at 10 to 15 days after anthesis
- This coincides with exponential growth phase of fruit
- Fruit size also strongly affected by environment
- Can we reduce discards and increase number of fruit at desired size for once-over machine harvest?

- Fruit length and diameter (and ratio) controlled by many genes (19 documented)
- This is a large number of genes to work with and take advantage of.

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Sheng, et al., 2019. Quantitative trait loci for fruit size and flowering time-related traits under domestication and diversifying selection in cucumber (*Cucumis sativus*). Plant Breeding: 10.1111/pbr.12754

Pan, et al., 2022 Phenotypic characterization and fine mapping of a major-effect fruit shape QTL *FS5.2* in cucumber, *Cucumis sativus* L., with Near-Isogenic Line-Derived segregating populations. Int. J. of Molecular Sciences: https://doi.org/10.3390/ijms232113384

TRAITS FROM GENE BANK COLLECTIONS OF CULTIVATED CUCUMBER

- Resistance to post-2004 downy mildew strains is found in accessions collected from India and Pakistan.

Wang et al., 2016. QTL mapping for downy mildew resistance in cucumber inbred line WI7120 (PI 330628). Theoretical and Applied Genetics: 10.1007/s00122-016-2719-x

Wang et al., 2018 QTL mapping of downy and powdery mildew resistances in PI 197088 cucumber with genotyping-by-sequencing in RIL population. Theoretical and Applied Genetics: 10.1007/s00122-017-3022-1

- Resistance to phytophthora fruit rot from India.

Colle et al., 2014. Screening the cucumber Plant Introduction collection for young fruit resistance to *Phytophthora capsici*. HortScience 49(3): 244-249.

- Some of these resistances are in lines with poor fruit quality so it takes time to transfer to pickling type background

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GENETIC DIVERSITY FROM *CUCUMIS HYSTRIX*

- Wild relatives of crops may hold genes for resistance to insects and diseases, tolerance to water or temperature stresses and possibly yield genes
- Cultivated cucumber is mostly incompatible with the majority of it's relatives. Genetic diversity is low. Is it a genetic dead end?
- Hybrids between cultivated cucumber and *C. hystrix* have been achieved using embryo rescue

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Delannay et al., 2010. Backcross introgression of the *Cucumis hystrix* genome increases genetic diversity in U.S. processing cucumber. J. Amer. Soc. Hort. Sci.: 135(4): 351-361.

John et al., 2018. On the taxonomic status, occurrence and distribution of *Cucumis hystrix* Chakrav. And *Cucumis muriculatus* Chakrav. (Cucurbitaceae) in India. Genetic Resources and Crop Evolution 65: 1687-1698.

Yang et al., 2014. Next-generation sequencing, FISH mapping and synteny-based modeling reveal mechanisms of decreasing dysploidy in *Cucumis*. The Plant Journal 77: 16-30.

Can we modify the shape of the plant to maximize yield?

- The gene CsBRC1 inhibits branching in cucumber. CRISPR Cas-9 gene editing might be one way to knock-out the function of this gene to increase plant branching.

- Tendrils use some energy to form and redirecting this resource to fruit production may provide an incremental yield gain. The *tendril-less* (*ten*) mutant replaces tendrils with branches.

- Leaf angle genes are known in several other crop species and can be used to reduce mutual shading and improve light capture for photosynthesis under dense planting. These are unexplored in cucumber.

Liu et al., 2021. Genetic regulation of shoot architecture in cucumber. Horticulture Research: 10.1038/s41438-021-00577-0

SUMMARY – SOME POSSIBLE DIRECTIONS

- Cold tolerance – possibly earlier planting, or to preserve yield in a variable (cool) growing season
- Increase genetic control of fruit size – combine multiple genes to reduce environmental effect, and increase flexibility of timing at harvest
- Disease resistance – post-2004 downy mildew, *Phythophthora capsici*
- Increase genetic diversity – from *C. hystrix* – expect genes for stress tolerance and possibly yield
- Modify plant architecture – to maximize photosynthesis in plant and resulting yield

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Thank you