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MURAJ: In Focus - The Budding Potential of Perennial Flax

By Allison Graper [1]

[1]*Department of Biosystems and Bioproducts Engineering, University of Minnesota - Twin Cities*

When walking with David Tork through his main nursery in Rosemount, Minnesota, there seem to be flax plants (*Linum* spp.) everywhere. Small light purple and blue flowers adorn uniform rows of green bush-like structures. One can't help but notice the intricacy of the plant's delicate flowers or wonder how seeds from these plants end up on our blue tortilla chips. I met with David to find answers to these questions and to understand his broader research into the variety of potential uses of perennial plants, including their ecosystem services in promoting the health of soil and water and providing forage for pollinators. I left our conversation amazed by the history of flax in Minnesota, with more appreciation for plant breeding and more knowledge of the contributions perennial flax has made to the broader goals of the Forever Green Initiative.

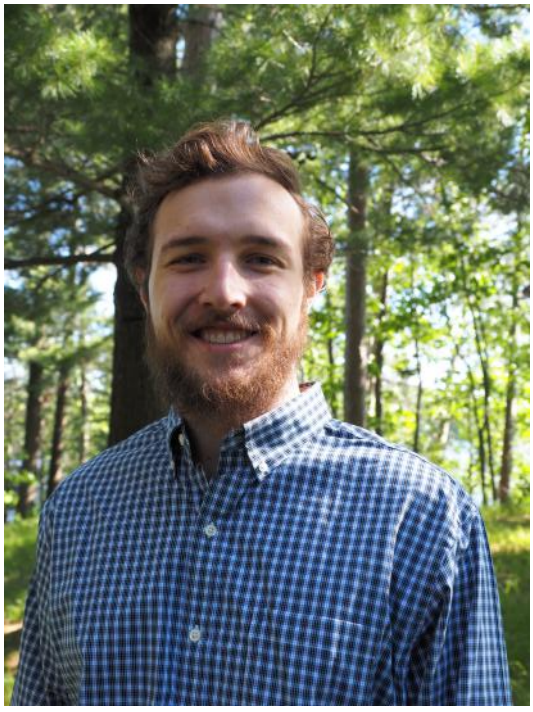

Figure 1: Master's student David Tork studying perennial flax in the Applied Plant Sciences program. Photo Credit: Hanna Hudepohlk

The University of Minnesota started researching perennial flax approximately fifteen years ago when Dr. Donald Wyse, currently a Professor and Co-Director of The Center for Integrated Natural Resources and Agricultural Management, traveled in the Black Hills of South Dakota and saw the potential of a perennial flax breeding program. He specifically noticed stands of wild Lewis flax (*Linum lewisii)*, named after the explorer Meriwether Lewis. David is the first graduate student working on the project, and before him, there was no funding for perennial flax research. When grant funding was secured, David was brought on board in August of 2018 to help expand the perennial flax breeding program at the University of Minnesota. There is an important distinction to be made between the perennial flax

that David works with and annual flax. Perennial plants survive the winter and come back for at least two to three years, whereas annual flax dies over the winter.

Historically, the University and the state of Minnesota were epicenters of annual flax from 1920 to 1950. Flaxseed oil was used in producing linoleum floors, paints, and varnishes. During World War II there was a large demand for varnishes and paints to protect military equipment that was fulfilled by flax seed production. Before cotton and weaving technology, flax was widely used in producing linen because of its long fibers.

The broad goal of David's research is to domesticate perennial flax for economic purposes and to explore the different potential markets for flax. Plant domestication involves taking wild plants that have existed for millennia in their natural habitat and breeding them for the best traits while discarding traits that are not useful. Common traits to breed for have historically been larger seeds, increased yield, non-dormancy (no delay in seed germination after harvest), and non-shattering seed pods (which do not drop mature seeds). Potential markets that have been already identified for perennial flax include seed production, ornamental greenhouse production (to be sold as a garden perennial), and cut flower markets.

David's research starts with creating ideotypes for the breeding program based on the requirements of these specific markets. Ideotypes provide an organizational framework and hypothesis of what the most ideal traits for flax would be based on their future use and purpose. This methodology gets everyone in his team on the same page and paints a picture of what they are looking for, David explained. The process starts with asking questions like: Should the plant be tall

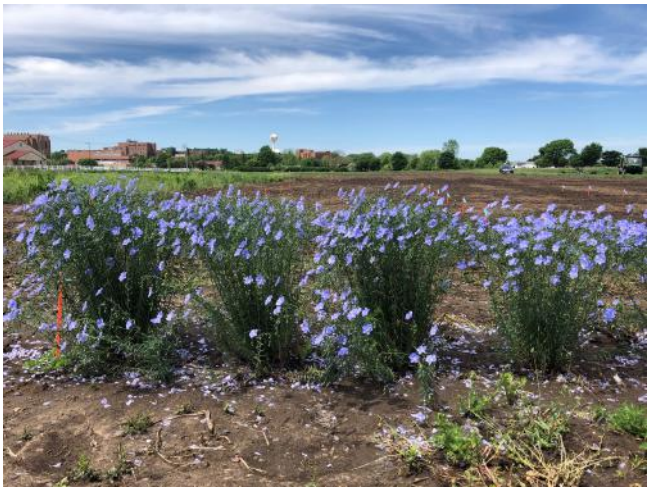

Figure 2: The ideotype plant for the cut flower market. Notice the long stems that branch at the top with numerous flowers. Photo credit: David Tork

or short? Should the stems branch at the base or the top? Should the flower petals overlap or not? The ideotype for cut flower plants have long and top-branching stems, with colorful flowers that hold their petals for over a day. The ornamental ideotype pertains to a plant with an abundance of flowers, dense foliage, summer-long blooming, and a uniform round shape. Lastly, the oil seed ideotype has large seeds and an overall high yield with non-shattering seed bowls and upright branches. While this seems like a lot of traits and variables, it is important for plant breeders to be specific on what the industry needs. Not meeting these needs can

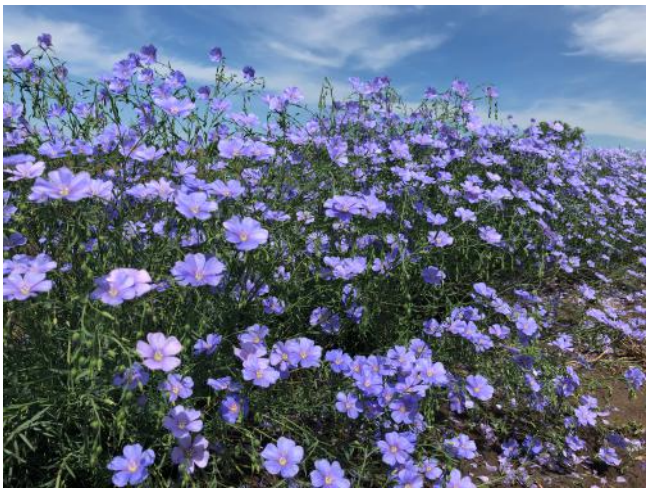

Figure 3: Ornamental ideotype for ornamental perennial flax with notable traits of dense foliage, round plant structure, and an abundance of flowers. Photo credit: David Tork

Figure 4: Ideotype for flax seed production with important characteristics of non-shattering seed capsule, high seed yield, and upright plant stature. Photo Credit: David Tork

result in a scenario like a plant with very high seed production that droops on the ground, leading its seeds to rot and the farmer to lose a harvest.

In order to breed plants for these three specific ideotypes, David's work revolves around a yearly cycle that is similar to other crops. For David, this translates to "spending the best part of the year outside and the worst part of the year inside." In the spring, seeds are sown in the greenhouse and planted in different field sites. David has plants throughout four sites in Minnesota as well as a site in West Virginia. The importance of having a number of different field sites is to account for environmental variability. Some genotypes perform vastly different in different environments and hardiness zones. Throughout the summer, David spends his time in the field taking field notes, collecting flowering data (color, size, shape, and number of weeks in flower), and measuring plant size (height, width, stem length, branch point, and stature). David says the most important part of summer fieldwork is, "watching at different points in the season, in different environments, and seeing how the different genotypes are performing across time." In the fall, the plants are harvested. Aside from the spring planting season, the harvest is one of the busiest times for plant breeders. "No spring vacations and no fall vacations," David jokes. Throughout the winter season, he works in the lab and on data processing. At this time, yield data collection occurs which includes measurements such as cumulative seed weight, seed size, seed capsule size, and the number of seeds per capsule. The last component of David's yearly cycle is planning for the next year by making selections. Selections are made by compiling qualitative observations, field notes, and quantitative data to decide which genotypes are kept and which are tossed.

When talking to David, he expressed the benefits of flax to both humans and environmental restoration. First, flaxseed oil is high in omega-3 fatty acids. This type of fatty acid is particularly beneficial to cardiovascular health in both humans and livestock. Flax also contributes to environmental restoration via positive effects on soil, water, and pollinators. Topsoil is the layer of soil that is nutrient rich and where plants grow, and Midwestern topsoil is some of the most fertile in the United States. Currently, crops like corn and soybeans cover Minnesotan fields in the summer. However, once the plants are harvested in the fall, fields are left empty and exposed to erosion from precipitation and wind through late fall, winter, and early spring. These empty fields result in an ever-growing loss in topsoil throughout the state.

Another large consequence of fields being left barren during the rainiest times of the year is field runoff. This runoff is usually high in nutrients like phosphorus and nitrogen that act as limiting nutrients in plant growth. Phosphorus and nitrogen are often deficient in the soil, causing farmers to supplement with fertilizers. When phosphorus and nitrogen are overabundant however, plants grow rapidly. Nutrients in these

fertilizers that are not absorbed by the plants travel through tile drainage and groundwater, or are washed away by precipitation as runoff. When runoff occurs, these nutrients end up in the nearest water body and are eventually deposited in the Gulf of Mexico via the Mississippi River. These pollutants contribute to algae blooms, eutrophication, hypoxia, and ultimately dead zones that cannot support life. With excess nutrients available, algae grow quickly and begin to dominate the ecosystem by reducing the amount of available oxygen for fish and other aquatic organisms. When the algae decompose, they produce an abundance of carbon dioxide that contributes to a lower pH and ocean acidification. This storm of events leads to unlivable conditions, known as dead zones, for plants, fish, and aquatic organisms with further economic consequences down the road. Closer to home, runoff can also make its way into our groundwater through infiltration and cause severe health conditions like methemoglobinemia (blue baby syndrome). This syndrome can be fatal and causes a baby's skin to turn blue along with difficulty breathing and other symptoms. Well water in rural Minnesota is broadly contaminated with nitrates as a result of agricultural runoff. Once a well is contaminated, expensive water treatment plans or drilling a new well are the only viable solutions. A perennial plant like flax would be able to combat runoff by soaking up water and sequestering nutrients in the soil. However, it is important to note that this crisis needs an extensive geographic solution– flax in Minnesota will help but cannot completely solve the problem.

Furthermore, flax contributes pollinator services to our state. Overall, there is a lack of pollinator forage in our landscape. Most Minnesota farm fields are covered by plants like corn and soybeans with very limited flowering windows.

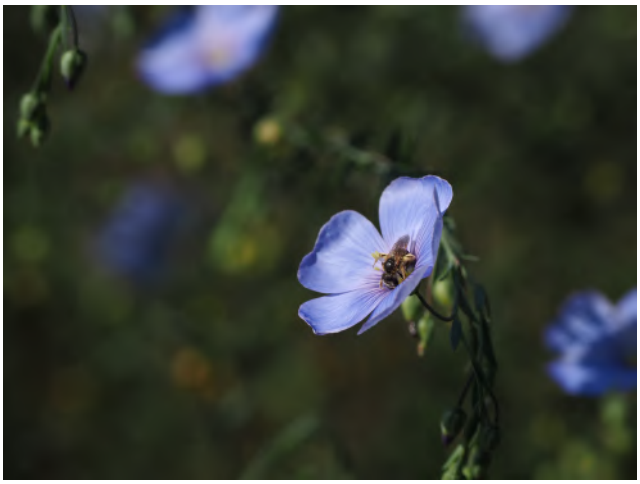

Figure 5: Perennial flax being visited by a pollinator. Photo Credit: David Tork

David explained the situation by saying, "it leaves massive gaps in the growing season where there is not a lot of food for pollinators." The agricultural dominance of corn and soybeans ultimately does not provide a sustainable and plentiful supply of food to our pollinators. Flax flowers early in the spring around May and produce flowers daily until as late as November, providing consistent and reliable food for pollinators.

David says that this is an intriguing aspect of flax and serves as an opportunity for further collaboration and research to find traits that attract pollinators. These traits may include things like flower color, shape, and pollen characteristics. An additional property of flax to be further investigated is its ability to uptake heavy metals and pollutants. Therefore, there is the opportunity for flax to be used at contaminated sites such as old mines where flax plants can uptake and concentrate pollutants. Flax would grant a simpler solution as opposed to removing contaminated soils completely with heavy equipment.

The Forever Green Initiative hopes that year-round flax cover on Minnesotan fields can help protect topsoil from erosion and increase its productivity. The project is in the state of Minnesota, with the goal of promoting soil and

water quality by implementing year-round cover over farm fields. This initiative includes numerous other plants like Pennycress, Hazelnut, and perennial sunflowers. A team of farmers, researchers, food product developers, and entrepreneurs work together to accomplish the goals of the Forever Green Initiative. David says that a big part of this project is to do outreach at events like the State Fair and to raise awareness of the goals of the initiative among Minnesotans.

David was raised in the Chicago suburbs of Illinois and obtained his bachelor's degree from the University of Minnesota in Plant Sciences. While originally intending to be pre-med, David found that Plant Propagation (HORT 1001) and his love for the outdoors directed his interest to the discipline of horticulture. In obtaining his master's degree, David has published his thesis proposal, received scholarships, and won the 2019 Crop Science Society of America photo contest (Figure 6). In reflecting on his experience, David encourages undergraduates to not just rely on their coursework but to join a lab and get involved in student organizations. David says, "labs are always looking for good people that are dedicated and interested in learning about what they are doing." When considering graduate school, David recommends finding a balance between what one enjoys doing on a daily basis, a topic that is intellectually stimulating, and a project that will equip you with skills for your future career.

Figure 6: David's award-winning photo in the 2019 Crop Science Society of America photo contest of flax exhibiting its heliotropic characteristics. Similar to Daisies, flax flowers follow the sun throughout the day. Photo Credit: David Tork

This profile is a part of the series MURAJ In-Focus, organized by the Minnesota Undergraduate Academic & Research Journal, with funding from the University of Minnesota Office of Undergraduate Education.

Allison Graper is a third-year undergraduate student in Biosystems and Bioproducts engineering with an emphasis in ecological and environmental engineering and a minor in horticulture. She is currently serving on the editorial board for the Minnesota Undergraduate & Academic Journal as the treasurer.