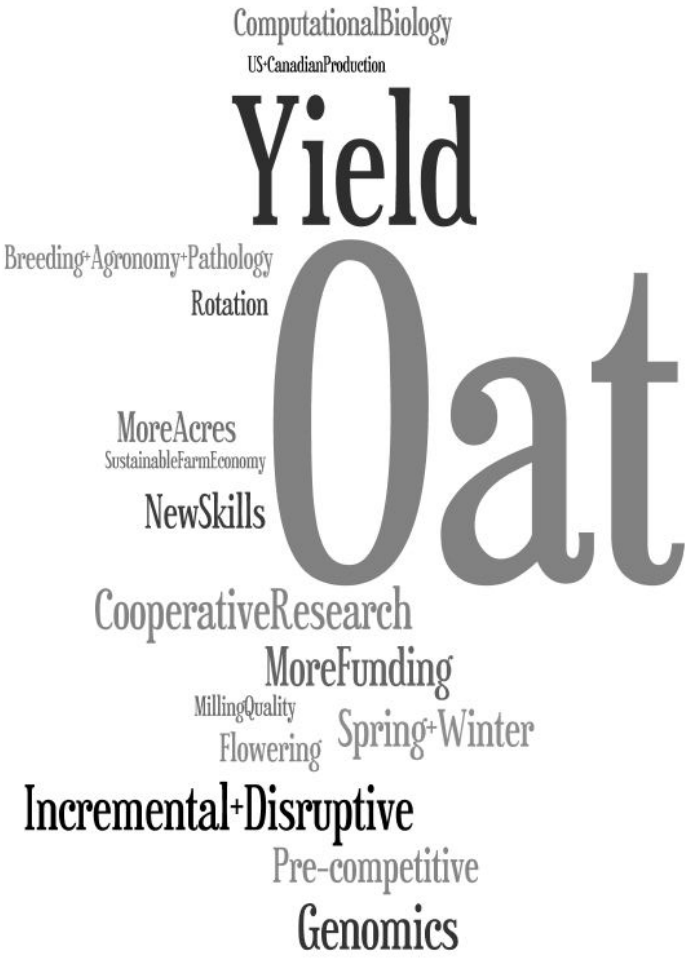
Oat Cooperative R&D: NAMA's View



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Executive Summary

New approaches to the oat research and development enterprise are needed to continue providing the milling industry with a reliable supply of high-quality oat at a price point that makes the whole value chain attractive for the industry at large, from the field to the retail stores and ultimately the consumers. Oat variety development has been historically based on incremental improvement for yield and milling and consumer quality but this model is becoming increasingly limiting due to the complexity of the traits of interest to the milling industry, and is too slow to deliver game-changing new product attributes that could energize the industry at large and directly benefit consumers.

In the last decade there has been a radical change in technologies available to crop improvement but the oat community has fallen behind in technology adoption due to organizational and funding challenges. Furthermore, the community has been significantly reduced in size to the point of serious concern to the North American Millers' Association (NAMA).

NAMA believes that a change in the historic model of innovation in variety development, followed by a new influx of resources and energy in the community, is necessary. New areas of fundamental sciences need to be explored to build the foundation of future innovation. Translational sciences need to be adopted: in a crop development context, this means a scientific approach to target setting and to mining of upstream knowledge. Public breeding programs need to rapidly and radically change their traditional ways of operating and move, even more than historically done, towards a networked model across sites and organizations. Lastly, a clear understanding and reciprocal respect of the pre-competitive and competitive spaces are needed to enable effective and purposeful cooperation towards pre-competitive targets, as well as effective competition for value-added traits that create financial incentive for the various players along the oat value chain (including generating revenues that can be reinvested in research).

However, an evolution of research objectives, a change in innovation models, and a shift in shared community reference values will not be sufficient to sustain the oat industry unless a significant increase in public resources and funding for cooperative oat R&D in North America (both in Canada and United States) occurs soon. Innovation will continue to be sluggish, oat will fall further behind other crops in revenue potential to growers and millers, and ultimately consumers will not reap the nutritional benefits of oats. Individual contributions from private or public entities to specific targeted projects, although useful, will no longer be sufficient: funding must be directed towards an up scaling of the technology platforms and the skill sets available to the public oat R&D community. New scientists are needed in the computational biology and quantitative genetics spaces and funding of research projects must rapidly shift towards technology-based breeding approaches. The areas of fundamental and translational sciences require dedicated funding.

While recognizing the great contribution of public research to the milling industry to date, NAMA with this document wants to challenge the status quo and contribute to setting new direction for the future of the oat R&D community and the oat industry in North America.

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Introduction

The North American oat research community, which includes public researchers, millers, and government organizations such as USDA-ARS and AAFC, is experiencing a period of transition due to concurrent events: the radical reshaping of the technological landscape, the continued evolution of trait targets of interest to industry and consumers, and the strong and established competition for R&D funding with other crops. In addition, this community has lost and continues to lose members due to retirement, elimination of positions, and decreased effort towards oat by scientists studying multiple crops. Funding is scarce and in many cases, despite positive intentions, not applied in a coordinated manner across organizations, whether public or private.

In the last few years the CORE initiative represented a first and well-organized attempt to orientate the community towards a new and more efficient way of operating by bringing together scientists around a set of foundational technologies. While this initiative has delivered new technology platforms that could potentially change the way this community operates, the community fell short of taking advantage of CORE for reshaping its internal relationships and leadership behaviors toward the enablement of a modern, effective, community-based, inter-agency, and inter-disciplinary R&D platform across North America and oat types.

In 2013-14, the community reconnected around a set of forums and discussion platforms that have allowed NAMA to observe and assess the current status of the community and its activity, receive direct input and questions from community members, and better define NAMA's role in bringing unified leadership from the milling industry to the community. As a consequence, a subgroup of the NAMA Technical Committee was created, the Oat Genomics Technical Committee, with the objective of providing, from a millers' stand-point, oversight and steering of R&D activities involving breeding, agronomy, pathology, or other disciplines related to the development and launch of oat varieties. In addition, an inter-agency and global forum called Oat Global Strategy Committee was created in 2014 to provide global leadership across organizations to public/private cooperative R&D in oat.

This document aims to provide NAMA and its oat members a reference strategy for the future of oat R&D for the development and launch of oat varieties. The document describes NAMA's vision and aspirations for a step-change in the ways the community operates, for a balanced approach to both incremental and disruptive innovation (regardless of the type of technology utilized), for a clear definition of the pre-competitive space, and for an effective cooperation between public and private scientists and funding organizations.

This document does not intend in any way to constrain freedom of choice or to suggest that only community-wide research projects should be undertaken. A diversity of approaches and a mix of community-wide or bilateral cooperation within the public and private community are extremely valuable: nevertheless, the small size of the community and the limited funding available for oat R&D will require a greater degree of coordination and global connection especially in addressing pre-competitive plant characteristics and agronomic practices.

Intentionally this paper defines "big, hairy, audacious goals" and its authors acknowledge that reaching those goals will be dependent upon increases in funding and technical opportunity. At the outset of the Space Race in 1962, President John F. Kennedy gave a speech at Rice University which can inspire us in the oat community to pursue goals which may seem impossible today: *"We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve*

to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too."

Accelerated Innovation and Cooperative R&D

While recognizing the great contribution of oat R&D to the industry to-date, NAMA believes that the historical rate of innovation is no longer sufficient to satisfy the business needs of the milling industry in North America. Fundamental changes are needed in oat as a crop to:

a. Make oat an attractive crop for growers, fitting well into a sustainable farm economy.
b. Create a reliable supply of high-quality oats that enables profitability and future sustainability for milling operations.
c. Meet food consumers' expectations of quality and nutritional value.

Disruptive Innovation and Incremental Improvement

Disruptive innovation is needed in order to rapidly reposition oats on the overall grain landscape: on the farm, after the farm, in the mill, and in front of the consumer. For the purpose of this document, "disruptive innovation" shall be defined as a significant change in an oat characteristic (e.g., a 20% yield increase, 10% consistent beta-glucan content, etc.) regardless of the technology utilized to deliver it (i.e., it does not imply "genetic engineering" or other specific technology). Disruptive innovation shall be delivered in a way that is rapidly transferable from the initial prototype or launch variety throughout the varietal portfolio, hence impacting the greatest number of final users in the shortest possible time. Furthermore, disruptive innovation shall deliver changes in oat's profile that reset the baseline for the industry as a whole. For example, yield improvement of 10% over the baseline in one variety, despite being impressive, shall not be considered disruptive without the ability to transfer the yield increase to other varieties and reset the baseline yield in oat. Yield improvement to such a magnitude, linked to technologies such as molecular markers or functional gene validation that enables both rapid transferability to other varieties and possibly mechanistic understanding of the biology of the improvement, instead, shall be considered truly disruptive and its pursuit supported with proper investments.

Although disruptive innovation changes the paradigm and propels the industry forward, thus generating significant gain for the community as a whole, it is unrealistic to expect that it will occur in short cycles. Therefore there is still need for incremental improvement for the sake of a sustainable baseline for the economic and technical attributes of oat. Incremental improvement, however, must occur at a much higher rate of genetic gain across the germplasm than has been historically achieved in order to meet the needs of the milling industry. The key attributes of incremental improvement that NAMA aspires to see realized are: (a) predictability, (b) target-setting, and (c) constant and reliable delivery across the germplasm. Incremental improvement with these attributes will constitute a solid foundation for the deployment of disruptively innovative solutions while maintaining the necessary oat acreage and economic infrastructure: investments in R&D are easily available and justified by the business space that they target, millers can continue building profitable businesses in oat in comparison to other grains, and consumers find satisfaction to their needs by using oat as an integral part of their diet.

NAMA believes that skillful combination of incremental improvement at a much higher rate than the past and cycles of disruptive innovation directed together at the same target is the only option for accelerating innovation in oat and shall therefore be supported as a matter of priority over other approaches. NAMA believes that a cooperative R&D approach will be the foremost enabler of such an innovation approach to oat R&D.

Cooperative R&D

NAMA defines "cooperative R&D" a set of activities and interactions among public and private researchers supported both by public and/or private funding aimed at shared benefits in the pre-competitive space. Cooperative R&D may come in multiple forms and may be implemented community-wide, among smaller groups of participants, or even with bilateral relationships between two organizations, depending on the size and complexity of the challenge to be addressed. However by definition in this document, Cooperative R&D shall target pre-competitive objectives and avoid creating advantage for a group with exclusion of the rest of the community.

Adoption of Genomic Technologies

NAMA does not consider rapid and widespread adoption of genomic technologies a matter of choice and a subject of validation any longer. These technologies have satisfactorily impacted other grain crops milled by NAMA members in the last decade, above and beyond their application in oat (e.g., maize, both field and sweet corn, and wheat). NAMA considers the current level of penetration of genomic technologies in oat research unsatisfactory and its rate of adoption unacceptable.

Now that genomic platforms have been delivered by the CORE initiative, and advances in technology allow for the continuous up-scaling of the informatics platform and a generally fast development of sequence-based genotyping technologies, NAMA suggests that the community needs to rapidly adapt to the use of these technologies and that the funding agencies need to determinedly evaluate and realign the availability of the necessary skills and expertise in the oat community. This subject will be addressed in various aspects in this document but it needs serious consideration and immediate action towards establishing a new and effective way of working across programs. NAMA calls upon the oat scientists to provide leadership in this direction, to set aside individual interests, and to set the course for oat to fully benefit, as soon as possible, from the latest advancements in genetics and genomics.

Pre-Competitive and Competitive Spaces

The pre-competitive, or non-competitive, space is defined in this document as the set of R&D targets and activities that benefit the crop value chain as a whole without positioning any given player to taking disproportional advantage over others. Therefore, knowledge and advances generated in the pre-competitive space shall be shared openly with the community. Pre-competitive traits are those that NAMA members prefer to see addressed by cooperative R&D approaches for the long-term sustainability of the crop (see next chapter for a list).

This attempt by NAMA to define the pre-competitive space shall not suggest that the competitive space be reserved to private scientists or that pre-competitive traits be the only targets for public researchers: every scientist in the community and every organization is free to participate in both spaces without restrictions.

Pre-Competitive Targets

The following is a list of targets that NAMA considers to be pre-competitive. This list is not meant to be exhaustive but rather to provide meaningful examples to provide guidance and provoke discussion. Other targets may be considered and added in the future.

- Plant habit: tall vs. semi-dwarf plants, degrees of tillering, upright vs. semi-prostrate, stalk strength.

- Ecology: daylight sensitivity, plant cycle (especially towards shorter seasons), plant density, water-use and nutrient-use efficiency (WUE and NUE), other characteristics underlying adaptability to production areas currently inactive (further North and further South), root system biology.
- Abiotic stress tolerance: Winter hardiness, germination in cold soils, seedling vigor and uniformity, tolerance to soil anoxia due to saturation by water, pH and salinity tolerance.
- Disease resistance at large, including new targets such as *Fusarium* head blight. It is to be noted, though, that the large emphasis given to disease resistance in breeding until now is perceived to have delivered to the detriment of effort dedicated to other fundamental traits and this is not considered acceptable.
- Herbicide tolerance.

Yield, Yield Components, and Crop Attractiveness to Farmers

Although it is recognized that the above list includes several yield components, a dedicated discussion to yield seems relevant due to its critical role in the economy of the oat crop.

Total realized yield at the farm gate has a direct impact on the profitability of oat milling operations; hence it has an element of competitive value. Nevertheless, the R&D around its components has a foundational impact on the overall economy of the crop for the whole value chain and is, therefore, considered pre-competitive. In particular, field yield should be regarded as one of many elements to be considered in driving increased attractiveness of oat for farmers both in the US and Canada.

NAMA believes that simply relying on higher yield *per se* will not be sufficient for oats to compete for land availability with other crops. Cooperative R&D efforts shall be dedicated to the development of varieties and agronomic approaches that close the gap between potential vs. realized field yield across environments, within the challenging financial parameters of input costs and achievable revenues, to expand the potential production areas to which oat is adapted both towards the North (Winter oats specifically) and the South of the current production areas, to introduce oats in a rotation scheme with other crops that bring advantage to the farmer such as, but not limited to, soil texture, structure, and health, abatement of disease inoculum in monoculture, water usage, and addition of another economic crop in the year (e.g., Winter oat between a corn and a soybean crop). The advantages of oat for farmers as a crop of medium to low input and financial exposure shall be studied as well and combined with a holistic oat crop positioning within a multi-crop farming system.

Agronomic practices shall be developed from a deeper understanding of the oat crop physiology and development. The interaction between oat physiology and environment shall be studied in relation to field performance and yield stability and predictability. WUE and NUE shall be studied in this context with an outlook on their impact on making oat a crop amenable to sustainable agricultural practices while delivering economic yield.

Oat Ecology and Adaptation: Spring and Winter Types

Current oat production for food use is primarily based on spring oat in Canada. NAMA believes that various drivers (changes in environmental pressure, competition with other crops for land, a growing demand for oats in the Southeastern US, a need for oat varieties adapted to organic production and competition with weeds, and a need for oats to become a short-season rotational companion to other crops) point in the direction of the future need for food-grade Winter oats in North America.

Until now the only research activities in winter oat for food use have been limited to sporadic trialing of Southern varieties in Northern US environments with the hope of finding varieties that would overwinter in such climates.

This is a valid approach but does not build the necessary genetic and physiological knowledge to drive the development of a whole new supply chain.

NAMA believes that the development of a winter oats supply for food use shall be accomplished by deploying the accelerated approach described earlier in this document. Just an incremental improvement approach based on Northern selection from the Southern programs or a selection for increased milling and consumer quality in the South for the South will be two relatively limited approaches that do not significantly change the paradigm. A comprehensive strategy that utilizes genomic tools to build the germplasm and trait portfolios necessary to enable the development of a winter oat industry that spans from the Southern US to the lower Midwest is needed over the next decade. Pushing the Northern boundaries of winter oat further North into the upper Midwest and Canada will likely become an objective of the following decade and shall be kept in consideration when designing foundational germplasm development and trait discovery projects in the first decade.

NAMA believes that the complexity of genes defining a Winter oat type shall be studied with whole-genome approaches targeting concurrently seed biology, plant development biology, and flowering biology, alongside the broader understanding of genetic tolerance to key abiotic stress factors. The whole-genome comparison between "Canadian Spring", "Midwestern Spring", and "Southern Winter" germplasm for the identification of haplotype blocks that underline the key adaptation traits that differ among these types and the level of variation present around those blocks shall be a high priority. Furthermore, daylight sensitivity genetics are likely to have a key role in this area of research and should be elucidated with high priority in oats in general (see discussion below as part of new targets for fundamental science discovery).

Industry-Shaping Seed Production Technologies

The oat seed production system and practices present significant challenges related to maintenance of purity and genetic performance when seed production is not performed using proper practices, resulting in seed mixtures on farm and genetic drift of the variety. In addition, the low gross margins associated with the current reproduction system in oat make this crop less attractive for impactful investment in R&D by the seed industry. Further, the self-pollinated reproduction system of oat offers little protection to seed companies wishing to deploy proprietary traits. The consequent requirement for legal protection tends to increase the time to commercialization of useful innovation.

NAMA believes a crop with higher uniformity and reliability of genetic performance and where proprietary and/or innovative traits can be brought to production quickly will benefit everyone along the value chain better than today. The result should be a change of the oat crop to a seed production method (either by genetics or by practice) that creates a business space for significant engagement of the seed industry in R&D and innovation and for a biological base of protection of unique and complex traits from dilution due to genetic drift over generations of seed increase. The history of seed production in other crops points towards the development of a hybrid system as a solution but this may be too extreme of a technical and financial challenge in the case of oat. Therefore, a more innovative and "blue-sky" approach may be needed, requiring thinking beyond traditional seed production and commercialization systems.

The development of novel technologies or approaches that could radically change the seed production system should be emphasized and supported. From a fundamental research standpoint, the understanding of the flowering biopathways in oat seems to be a useful element of this evolution and will be discussed further below in the document.

Milling and Consumer Quality as Competitive Targets

Any trait or practice related directly to milling and consumer quality is considered by NAMA to fall distinctively in the competitive space. NAMA recognizes that there may be components of foundational knowledge that could be best investigated with a cooperative R&D effort in order to accelerate scientific discovery in those areas. However, NAMA also recognizes that it is too difficult to *a priori* delineate areas of potential concern and at what point in the scientific discovery process a competitive element is generated. Therefore, NAMA encourages the community to openly discuss possible opportunities and accept that NAMA as a coordinating body may not be in a position to support such research efforts and will need to delegate to its individual members for their independent consideration.

From Fundamental Research to Variety Development and Trialing

Fundamental Research Aspirations

NAMA believes that new areas of fundamental research shall be opened over the next decade as a foundation for future innovation. Although not an exhaustive list, NAMA below wishes to suggest examples of areas of interest to its members that shall be considered by the oat community and funding agencies.

- General yield and economic sustainability:
  - Yield in oat must increase (farm yield and milling yield) in order to make this crop economically competitive with other crops.
  - Study of the linkage of yield in oat to farm practices and rotation with other crops.
- Physiology of oat development for:
  - Adaptability to new areas of production further North (Winter oats) and South (both Spring and Winter types).
  - Determination of optimum agronomic practices for maximum yield and quality combined.
  - Role of the root system in oat production and its impact on WUE, weed suppression, and soil structure after the cropping season (linked to rotational companion role for oat).
  - Ideal plant habit for maximum yield and quality.
- Multi-trait Biopathway Exploration: Understanding biochemical processes underlying key traits by examining synthetic relationships (a.k.a. biological similarities) with other crops and validating that these processes function similarly in oat as in other grains.
- Mating systems and flowering biopathway control.
- Durable disease resistance systems.
- Crop management practices from planting to delivery to final point of use:
  - Input management (fertilizers, pesticides, growth regulators, irrigation, etc.).
  - Cultivation and harvest practices.
  - Storage technologies for quality retention (ground piles, silos, bags, etc.).

Translational Research and Objectives Setting

Fundamental research will help improve the understanding of the genetic elements behind traits of interest and variety breeding will provide a delivery platform for combining multiple complex and simple traits in innovative varieties. To complete the breeding process, much greater efforts in translational research are needed in the oat community to:

- Bring upstream knowledge to fruition in the breeding programs.
- Define breeding objectives for baseline improvement and game-changing traits.

NAMA would like to see more active experimentation so that breeding objectives can be defined based on data and knowledge rather than surveying the milling community (e.g., experimenting and publishing what the ideal minimum level of oil content could be before kernel breakage is too high to be economical in a milling context). NAMA believes that the public community is the best positioned to actually push the boundaries of current industry understanding and perception on the attainable level of expression of traits. This suggests that scientists should have funding available for studying traits and setting technical objectives.

Once this approach is embraced, the issue of determining traits and related measurement techniques for competitive traits will become less sensitive. Commercial checks and the newly-developed understanding of the genetic potential of a trait in combination with others will allow breeders to set their own targets and to breed varieties that go beyond current industry standards and perceived room for improvement.

Breeding

Overall more effort in breeding oat varieties, both Spring and Winter types for Canada and United States, is necessary to support the needs of the milling industry and to develop alternative supply production areas as a way to manage supply risk due to changing climatic conditions and logistical difficulties associated with a strained North American transportation infrastructure.

Pre-Breeding vs. Variety Development

During a recent public discussion a direct question was asked by public breeders: should public researchers in oat focus on pre-breeding and leave variety development to private entities or should they continue to breed new varieties? To a straight question, a set of straight answers:

1. Public breeding of commercial varieties must continue. The oat industry needs a diverse community that applies diverse approaches to variety development and drives towards both competitive and pre-competitive targets combined in varieties with a complete trait profile. Furthermore, not all millers are vertically integrated and have access to an exclusive breeding program. In addition, the seed industry is not currently investing in oat breeding in North America at any significant rate. Therefore, it is of critical importance to NAMA that public breeding for variety development continues to exist.
2. Public breeding is severely under-supported currently in North America both in the number and size of breeding programs. This must change and NAMA aspires to partner with public funding agencies to help accelerating this change. It is commendable to see the hiring of successors to retired breeders at some universities (e.g., South Dakota State University and University of Florida in the last several months) but the limited number of such hires will not increase community size and diversity to an acceptable level.
3. New breeding programs should be established that target production areas for the future, especially linked to the winter oat discussion in prior chapters and to the expansion of the spring crop back into the US.
4. However, a balance must be established between pre-breeding (germplasm development and trait research) and breeding. It is NAMA's assessment that the majority of effort in the past has gone towards breeding based on incremental improvement of varieties and this is not considered to be an acceptable dedication of resources in the future (refer to "Accelerate Innovation" chapter above).

5. Lastly, the current and new breeding programs will need to demonstrate their embracement of modern technologies in the genomic and data-driven R&D space in order to garner NAMA's support moving forward.

Breeding as a Network

Traditionally oat breeding in North America has been conducted to a large extent primarily via local and locally focused activities (i.e., breeding in the target market for the target market). Breeders have been cooperating increasingly across breeding programs, and millers and growers have been sourcing varieties bred for one environment and advocating their use in other environments. Nevertheless, NAMA believes that there is room for further cooperation across the community and that breeding based on genetic potential rather than organizational remit of local entities is the best chance for widespread adaptation and success in the future: as a result, a breeding program in one state/province may end up breeding varieties more suited to other locales in addition to traditional varieties adapted to local growing conditions. Although recognizing that various agencies and universities operate under mandates and established frameworks that cannot be readily changed, NAMA believes that technical strategies can be adopted to move towards a very effectively networked breeding approach with an eye to a more holistic understanding of meeting local economic needs through cooperative research. Specifically, NAMA recommends the following:

1. Germplasm management techniques shall be applied community-wide via the combination of genomic and performance data so that the best germplasm can be adopted for the best purpose and that the coancestry between germplasm pools can be unveiled and exploited beyond the traditional target markets of a given breeding program.
2. A consistent approach to genomic-based breeding is urgent. Big differences in approach currently exist such that some breeders apply only single gene markers and some utilize genome-wide marker-assisted selection methods. This stratification is detrimental as it creates pockets of "technification" and a limited effort towards adoption and optimization of a given technology.
3. Multi-state and multi-disciplinary "breeding teams" shall replace individual and isolated breeders with the goal of increasing the rate of gain for complex traits (incremental improvement) while enabling the discovery and deployment of disruptively innovative genetics. This will require a shift in reference values from cooperation for a specific purpose to a truly open concept of reciprocity in R&D, where the total of the parts (contributors) is always greater than the sum. To this extent, three areas of urgent and more open collaboration are recommended:
    a. Open sharing of pre-competitive data in one database is necessary. This will require changes in ways of working and adoption of community-wide databases rather than personal IT solutions. NAMA recognizes that this change may be inconvenient to some but it will greatly benefit the community and the industry at large. Therefore, it is deemed to be necessary and urgent.
    b. Adopting genomic breeding technologies immediately presents the challenge of increasing skills in computational biology and quantitative genetics in the breeding teams. Since financial pressures make it unrealistic to expect that every breeding location can hire new employees with these skills in the short term and since not all individual breeders may have enough time and resources to be independent in these areas, NAMA strongly urges the community and the funding agencies to develop a cohesive strategy for sharing computational biology and quantitative genetic resources across organizations and countries.
    c. Due to location or personal expertise, each breeder in the community has a different and unique skill set that can be contributed in a team-based approach to variety breeding. These differences

shall be recognized and celebrated in a shared leadership model where every member of the community leads the community around their specific area of expertise rather than leading a breeding program by location as a self-sufficient isolated unit. This will require a significant change in reference values and NAMA encourages the organizations funding and administering the breeding programs to facilitate this transition and reflect this need for change in their strategies and award and recognition policies. Collaboration and networking shall be recognized as the "new normal" rather than an example of exceptional performance.

d. The concept of "centers of excellence" should be explored and expertise and specialization of certain locations and teams should be openly recognized and encouraged.

Ultimately NAMA would like to see the breeding focus shift over time from an insular local funding model to a more comprehensive approach which concurrently serves the current markets, enables the opening of new production areas in North America, and contributes the breadth of knowledge and experience present in North America towards other countries where oat production is or may become of interest. To the latter point, international cooperation with countries that can provide a unique edge in certain research areas but are not traditionally areas of commercial production of oat may open new possibilities for exploring new traits or wider adaptation while enriching the short-term toolkit available for breeding for current markets (e.g., should North Africa be considered for WUE trait dissection and allele frequency management?).

Trialing

Trialing of new varieties and deeper study of genetic-by-environment (GxE) interactions for pre-competitive traits should also become a more shared effort in the public community, above and beyond the current uniform nursery and variety registration trials. This will require the coordination of larger trials in more environments and the federation of resources and efforts, along with the contribution of information into one database shared within the community. Guidelines will need to be developed to allow for the contribution of performance information in a way that protects the IP rights of the contributors while enriching the base pool of data that builds over time for the understanding of GxE interactions for complex trait combinations and under evolving agronomic practices.

A major recognized gap in platforms that has been hampering trialing efforts for a long time is the ability to develop and share uniform quality data for milling and consumer traits in a public laboratory and across Canada and the United States. This is a complex issue because these are considered highly competitive trait areas and little knowledge will be shared by the milling companies with the public community as to preferred targets and measurement technologies to be adopted. Therefore, NAMA highly recommends the development of public protocols and possibly the funding of one consolidated platform for the analysis of trial samples for these traits. Ideally one or two laboratories would be created by public agencies with the remit to their directors to maintain aligned protocols so that data can all be shared openly in the community in one database and compared seamlessly. NAMA considers this capability fundamental for a greater understanding of GxE relationships for these traits that lift the overall industry while protecting the competitive knowledge and technologies that each miller has developed and maintained secret over decades of investment.

Funding Mechanisms and Advocacy

The oat R&D community in North America includes researchers reporting into various public and private organizations, such as USDA-ARS, AAFC, various universities, and private breeders and millers. Therefore there are

multiple avenues available through these organizations for funding cooperative R&D. In addition, various public grant programs are available that should be accessed.

NAMA encourages the community to conduct fundraising for cooperative R&D in a coordinated manner and by accessing multiple funding sources concurrently. NAMA aspires to see more public grant applications submitted for larger cooperative studies than in the past. In addition, a direct and open discussion across organizations should be active for identifying the best options for synergistic funding. To this extent, the Oat Global Strategy Team and Initiative provides an additional forum for stimulating this discussion and matching sources and applicants for funding.

Public breeding programs working in the pre-competitive space or willing to compete in the competitive one should be better funded by their sponsoring agencies and governments. NAMA is willing to interact with the sponsoring agencies to help identifying business needs and justifications for further investment.

Inter-institution funding shall be explored more often due to the multi-disciplinary aspect of the needed pre-competitive research in oat. Furthermore, cooperation and co-funding between public and private, and between US and Canadian entities shall be pursued more frequently both for small and large initiatives.

All members of the oat research community have a responsibility to advocate for the efficient deployment of resources currently devoted to oat research. To move beyond the current era of incremental advances in breeding, new resources must be brought to bear. NAMA itself could be a source of funding for cooperative R&D. However, NAMA will preferentially support projects that are utilizing modern technologies for increasing chances of success and accelerating genetic gain.

NAMA will refocus its advocacy efforts within the United States Federal Government to direct additional resources towards oat breeding. Further, NAMA will work with partner grower and processor organizations in Canada to ensure that researchers on both sides of the border have the capacity to advance oat research in the twenty-first century. The aforementioned environmental, economic, and nutritional benefits of increased North American oats cultivation and consumption will be highlighted in an effort to increase public support for oat research in both nations.

The oat community has a proud tradition of high-quality research: NAMA believes the time is right to build upon this history and move forward into a new era of oat breeding and agronomy.