



C4F-
REPORTS
AND
RESEARCH
PORTRAITS

PICTURE: LI HUA ZHU

C4F- Crops for the Future

C4F has continued to serve as a research platform, supporting numerous research projects connected to other large initiatives or programs funded by various agencies. In 2024, one project was successfully completed with one PhD student defended working on the project, and one new project is set to begin in 2025. Overall, the program's research progress in 2024 has proceeded as planned. A number of high-quality peer-reviewed articles have been published, with additional manuscripts accepted, submitted, or in preparation for publication. Furthermore, new PhD students and postdocs have been recruited to work on different projects. The annual C4F workshop was successfully held in December.

The post-doc on the Green diapers superabsorbents project started with the fractionation procedure of the proteins from green biomass in order to get a higher yield of proteins to be used for absorbent materials. A wide range of extraction procedures have been evaluated and the manuscript on this work is soon to be submitted. The work on evaluating the path of the nitrogen in the green biomass was published in 2024. The work on evaluation of the green juice fraction, collected earlier from the Plant Protein Factory, for its suitability for superabsorbents production is ongoing and will be finalized during 2025 with a manuscript.

Plant protein fractionation research has its focus on understanding how proteins can be fractionated and thereafter used for production of various types of materials such as superabsorbents, currently focusing on wheat gluten and potato proteins as well as green biomass proteins. The work is progressing well with the first two manuscripts on wheat and potato proteins to be drafted early 2025.

Wheat genetic research focuses on understanding the genetic background for various quality traits. The project is progressing very well and three peer-reviewed papers were published in 2024 along with an introductory paper. Additionally, Yuzhou Lan defended his PhD thesis. Furthermore, more manuscripts are in pipeline.

The overall progress of the two projects - green and model protein systems and MAX IV techniques, highlighted that ultra-processing is a pre-treatment method positively impacting the functional properties of the legume proteins in diverse food systems. X-ray tomography was found being a useful tool to probe morphology of the diverse protein systems. Three manuscripts are in pipeline.

The research on faba bean and faba bean-oat tempeh-like products revealed enriched texture, taste, and moisture by semi-trained panel and instrumental measurements. Fermentation increased protein digestibility and reduced phytic acid. Microscopy showed structural changes, confirming biotransformation into nutritious, high-quality, and tasty food with positive sensory acceptability.

The final experiments to be performed at KTH for PhD student Shishanthi Jayarathna were successfully completed, compiled, and integrated into the last paper of her thesis. Her two previous papers were revised and published in 2024. She completed and successfully defended her thesis.

Camelina sativa transformed with genes derived from *Lindera* for medium chain fatty acid synthesis were successfully evaluated. *Camelina* PacBio long read genomic sequencing resulted in information for a coming manuscript and has been

used for defining gene editing targets. *Camelina* genes as targets for gene editing have been experimentally verified.

For improving the traits of oil crops, more CRISPR-edited mutation lines of rapeseed targeting genes associated with seedcake quality have been developed or are undergoing further evaluation in the biotron. Chemical analyses indicate that some edited lines have exhibited desirable improvements in the target traits.

For high-throughput screening of EMS-induced mutations, M3 seeds of selected mutation lines of rapeseed grown in the greenhouses were obtained with assessments on some phenotypic traits. Chemical analysis via NIRs was performed on some lines. Furthermore, DNA samples were prepared for molecular analysis.

Gene edited events for the potato tuber, sink and starch research, have largely been finalized for enhanced tuberization, improved heat tolerance, adjustment of the biological clock for long day sensing, and improved starch quality and productivity. The next step is to evaluate these events in the biotron under a range of controlled environmental conditions.

Synthetic wax esters from plants research went well in 2024. It was further enriched by a six-month scientific visit by the young researcher, Kamil Demski, to the University of North Texas, as well as the integration of bioinformatics studies focusing on jojoba germination.

As to plant autophagy, we completed our major tasks, and the resulting findings have been now summarized in a manuscript accepted for publication in *Nature Communications*. In addition, Florentine Ballhaus undertook a two-month research visit with Dr. Kim Boutilier at Wageningen University.

With the final goal to enable cheap and rapid evaluation of forage quality parameters for individual harvests, we have collected data on yield and forage quality parameters from three sites (Svalöv, Uppsala, Umeå) and from two consecutive years. The data have been collected and analyzed together with Lantmännen Lantbruk AB.

Within the C4F program, research outcomes and associated outreach activities deal with new knowledge and information on novel potential uses of plant oils, proteins, starches and other compounds from side streams, which can be used as food, feed and industrial applications. The program has contributed to generation of novel plant materials for further breeding or direct uses in product quality research and future potential applications, applications of novel technologies such as CRISPR-mediated genome editing, next generation sequencing and MAXIV techniques and emerging of new research areas such as bio-based composites for food and non-food uses, possibility of crop improvement by regulating autophagy process, and renewable sources of plant produced insect pheromones for pest management. SLU Grogrund has continued to support continued or new projects in 2024 and some of them are directly connected to the C4F projects.

Detailed research findings and progress

The study of the nitrogen (N) path while fractionating green biomass showed: a) N was present mainly as amino acids (AA) in all fractions. b) The protein was partly degraded or insoluble in the majority of samples. c) All protein types and AAs travelled similarly through the fractionation process, giving insignificant separation of RuBisCO versus other proteins, and essential versus nonessential AAs. d) Water-soluble N compounds were enriched in juice fractions (90–95%), while the protein fractions contained the highest insoluble protein content (13–17%). e) AA composition in pulp and

green juice verified their suitability as feed for ruminants and pigs, respectively. f) Fractionation of green biomass for food and feed is important, although for sustainable industrial applications, further evaluations are required regarding process feasibility, antinutritional components, and brown juice uses. The study on the protein extractability from the pulp fractions showed either an extra extraction with water or with NaOH as the most sustainable and economically feasible alternatives. Moreover, freezing of the samples affected the protein extractability significantly.

The plant protein studies showed that the glutenins and gliadins behave differently as to swelling behavior as well as regards functionalization and cross-linking behavior. The best swelling behavior was obtained for the most purified samples of glutenins (Fig. 1). The molecular bases for these results are currently under evaluation from the RP-HPLC, SE-HPLC, FT-IR, NMR, TGA and DSC results that we have obtained.

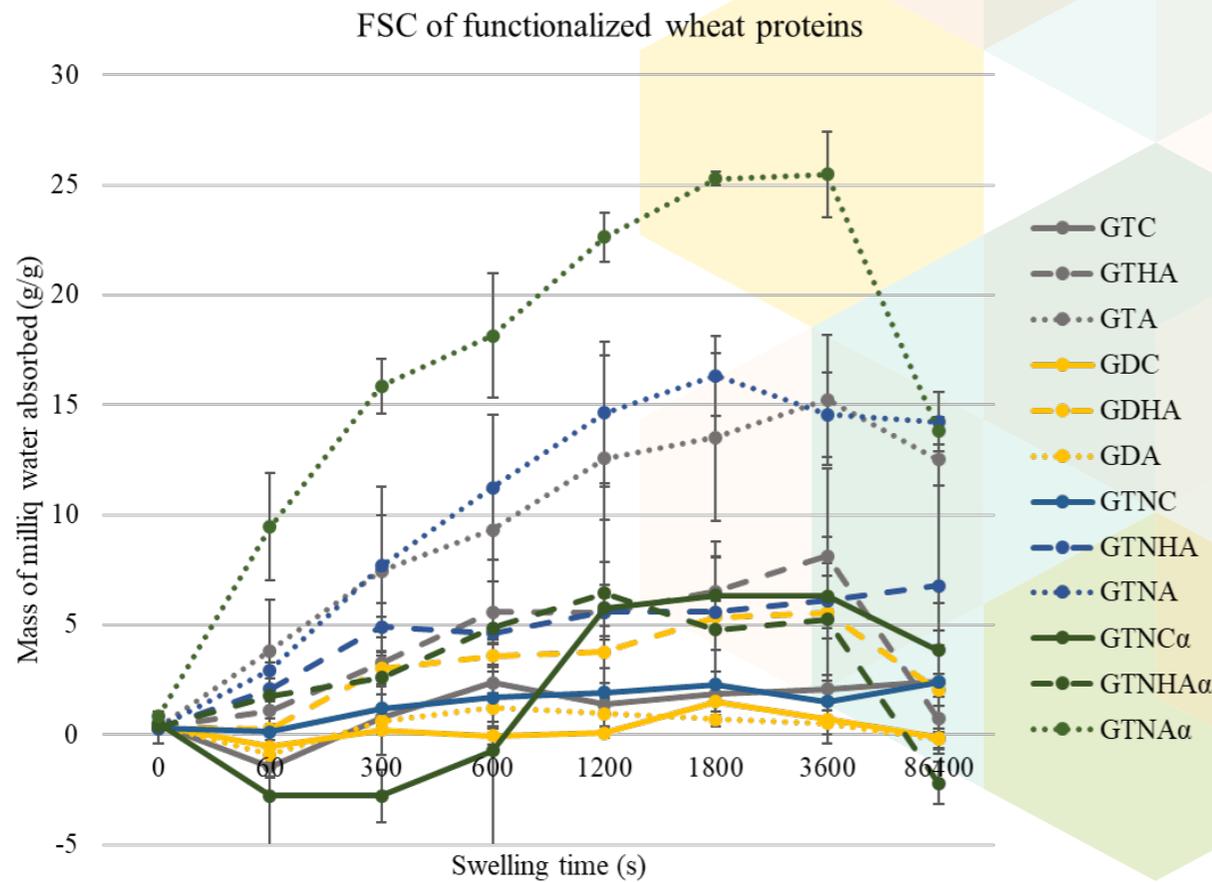


Fig. 1. Free swelling capacity (FSC) of gluten, gliadin, glutenin and glutenin treated with alpha-amylase over time. The samples are divided into non-treated control (full lines), heat and alkali treatment (dashed lines) sample and functionalized (dotted lines) which is treated by heat, alkali and EDTAD. (Figure by Maya Sétan DIAKITÉ).

Wheat genotypes with rye chromosome 3R introgression showed high Zn and Fe accumulation, stable across drought conditions, while chromosome 1R contributed to high Se content. Old cultivars excelled in early drought mineral yield (K, Mg, Na, P, S), and 2R lines performed well in late drought (Fe, Ca, Mn, Mg, Na). Cd accumulation was higher in old and 1R genotypes, with genotype 207 showing extreme Cd levels under all conditions. Late drought increased Cd uptake in modern, 1R, 1RS, and 2R genotypes but not Pb or Hg. Hg levels remained high in 1R and 1RS genotypes, while 3R lines had low Cd accumulation. Late drought restricted yield more than early drought, though old and 1R genotypes had longer roots for water access, linked to elevated Cd content (Fig. 2). Despite a general protein-yield tradeoff, 3R lines achieved high protein and yield, offering breeding potential (Fig. 3). Biostimulants improved yield under drought

stress. Thus 3R spring wheat genotypes were found positive for grain yield, minerals content and low cadmium content and should therefore be further evaluated in breeding.

The main findings in the legume protein use in colloidal and solid food systems pointed out the importance of the pre-treatment of proteins. This allowed to create some diversity in micro-structures in the two legume protein types (Fig. 4) and this diversity was due to the origin of the protein and their response to the pre-treatment. With our research we showed that the foaming properties were better in one of the studied legumes compared to the other, and that was positive for the targeted foamed foods. In the biobased fiber study we showed novel materials developed from the wheat gluten proteins in combination with other crosslinkers and biopolymers. These materials were superior in terms of mechanical performance.

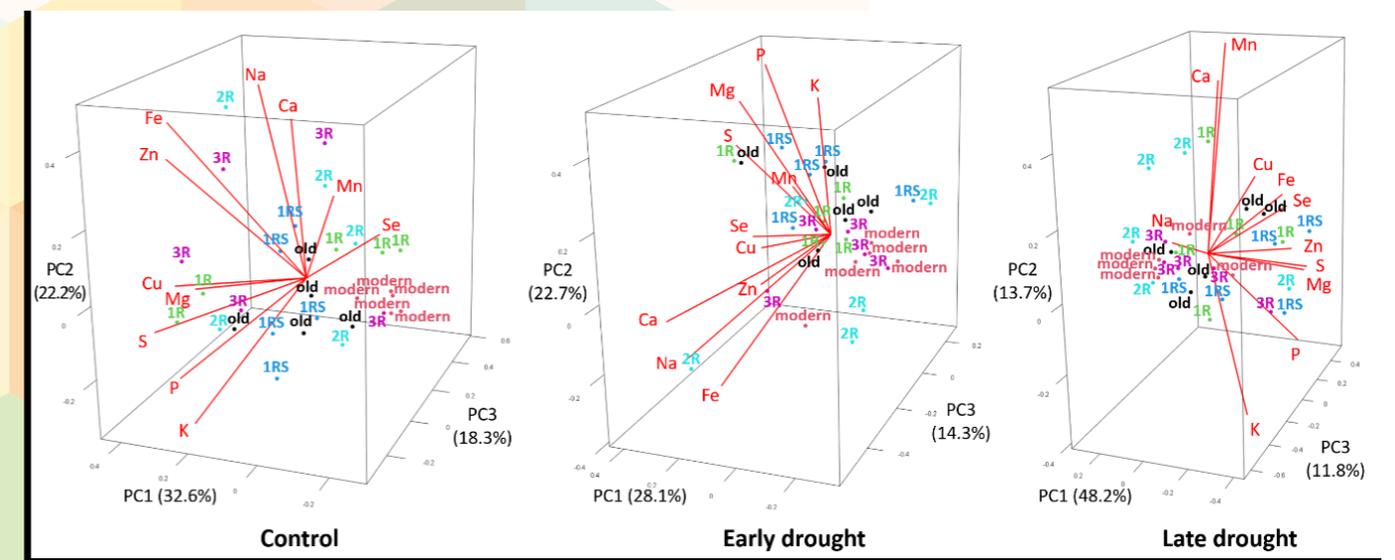


Fig. 2. PCA plots showing relationship between concentration of different minerals and different wheat genotype groups under control, early drought and late drought conditions. (Source: Lan Y, Kuktaite R, Chawade A, Johansson E (2024) Chasing high and stable wheat grain mineral content: Mining diverse spring genotypes under induced drought stress. PLOS ONE 19(2): e0298350. <https://doi.org/10.1371/journal.pone.0298350>.)



Fig. 3 Left: Collecting biotron-grown and drought-treated wheat samples for grain yield, mineral and protein analysis. (Photo by Yuzhou Lan). Middle: Preparation of samples for sensory evaluation at the Food and Meal Science department, Kristianstad University, Sweden. (Photo by Marcus Johansson). Right: The project evaluation fields at Lantmannen station in Bjertorp, from right to left, Karin Wendin, Tina Henriksson, Olawale Olalekan, Karin Gerhardt, Thomas Björklund and Mahbub Rahmatov. (Photo by Muhammed Elsafy).

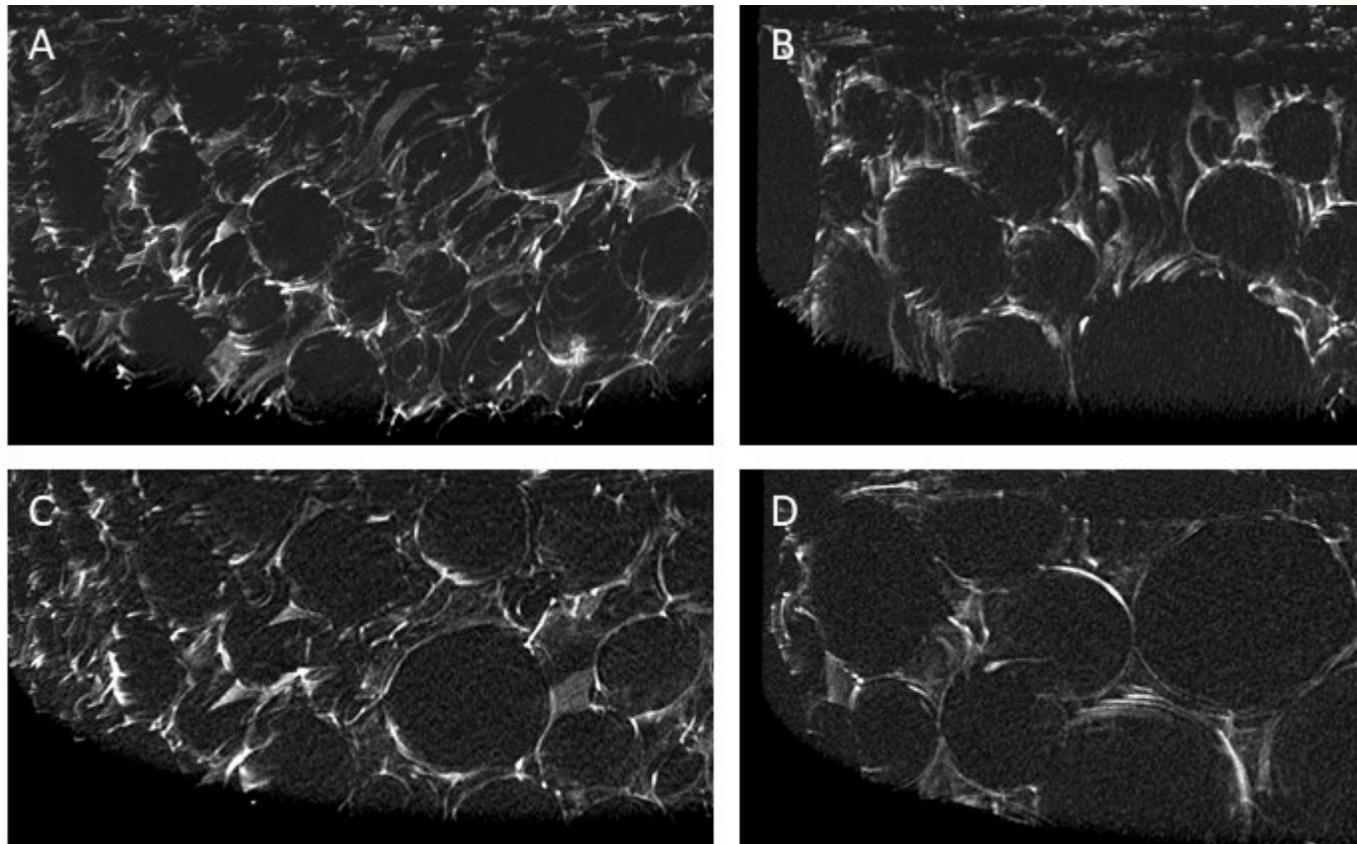


Fig. 4. Legume protein foaming after ultra-processing. A: Control faba bean protein foam. B: Ultra-processed faba bean protein foam. C: Control pea protein foam. D: Ultra-processed pea protein foam (Photos by Ramune Kuktaite).



Fig. 5. Alejandra Fernandez from SLU and Shania Saini from University of Turku doing GC-MS volatiles compounds analysis on faba bean tempeh. Tempeh and meal with tempeh made from SLU (Photos by Alejandra Fernandez).

The study optimized tempeh production from faba beans, highlighting sodium bicarbonate with *L. plantarum* (SbL) as the most effective soaking medium, reducing boiling time by half of the time with 8 minutes needed (Fig. 5). The SbL protocol produced tempeh comparable to traditional soybean tempeh, with favorable attributes such as optimal final pH, texture, colour and moisture. (<https://doi.org/10.3390/fermentation10080407>). The second study investigated sensory parameters in faba bean and oat tempeh-like products using *L. plantarum* soaking. We found reduction in beany off-flavours and enhancement of “masking” flavours compounds such as sourness, umami, as well as increase on the chewiness. Cooking amplified acids and pyrazines. Sixty-five volatile compounds were identified, including 3-methyl-1-butanol and acetoin. Texture improved significantly with oats, while moisture remained unchanged. Hedonic testing (n=107) indicated acceptable liking for the faba bean-oat mix tempeh, highlighting the role of pre-treatments in enhancing sensory quality and acceptability. Manuscripts are in pipeline for publication.



Fig. 6. CRISPR-edited lines of rapeseed grown in the biotron. Left: Flowering stage. Right: Seed mature stage (Photos by Li-Hua Zhu)

Two papers were published during 2024 related to the novel potato protein research. The first one was a paper on potato starch with SBE mutations in combination with GBSS mutations. The main finding in this paper was that the combination of these mutations could partly restore granule morphology as well as their internal ordered structure. The second published paper added information about the starch granule phosphorous as well as physical and material properties. It was a collaboration with an NMR expert at SLU and material experts at KTH. Briefly, the results showed that mutations in SBE significantly increased the starch-bound phosphorus content. Material properties experiments showed that starch with a large proportion of long chains was suitable for making starch films. Starch material is generally a good oxygen barrier, and this property was preserved in the films made from our novel starches.

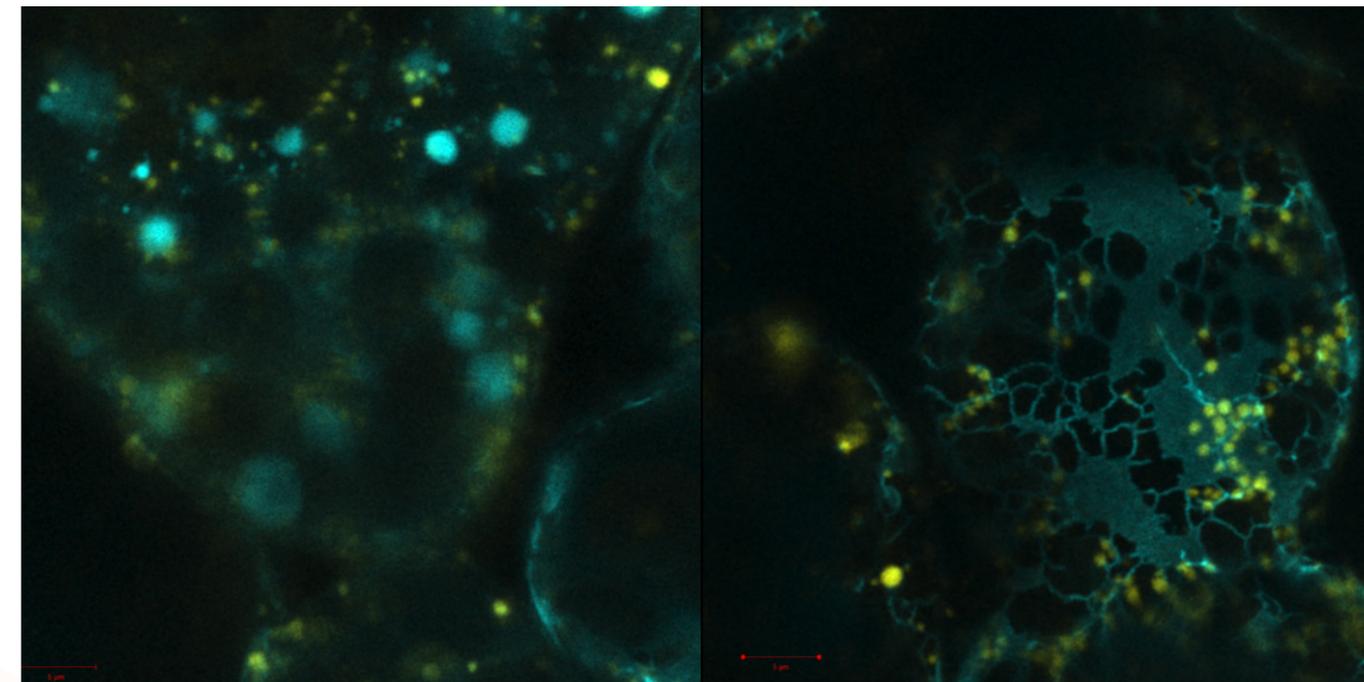


Fig. 7. Confocal microscopy images of transformed leaves of *Nicotiana benthamiana* from the transient leaf expression experiments. Both samples were stained with BODIPY to elucidate lipid droplets and contained a vector expressing CFP-ER marker. The photo on the right shows a sample synthesizing wax ester without the addition of LDAP1 and LDIP genes from the jojoba lipid droplet packaging machinery. The lipid droplets are not uniform in style and there are swollen, malformed regions of ER present. The photo on the left shows a sample synthesizing wax esters with the addition of jojoba LDAP1 and LDIP. The lipid droplets are more uniform, and the ER is properly formed throughout the sample (Photos by Kamil Demski).

Camelina plants engineered for medium chain fatty acid accumulation have been characterized and will be the focus of an upcoming manuscript. Genomic sequencing of a previously transformed event will be the basis of a manuscript in combination with generational data and homozygosity studies. A new strategy for regulating enzymatic activities towards 14-16 carbon fatty acids, without the use of foreign gene activities, has been initiated with very interesting observations to follow up during 2025.

Using our efficient protoplast regeneration methods, we have generated several transgene-free mutant lines via CRISPR editing, currently focusing on rapeseed and *Lepidium*. Some of these lines, along with previously developed mutant lines

across different generations, have been evaluated in the biotron for phenotyping and genotyping (Fig. 6). Chemical analyses targeting key traits in rapeseed revealed mutant lines with significantly reduced seed sinapine or glucosinolate contents. Some of these lines are already homozygous for the target traits, while others will continue to be evaluated in 2025 to achieve homozygosity as well as phenotyping and genotyping. One manuscript detailing these results has been accepted by *Frontiers in Plant Science* (<https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2024.1526941/abstract>) and several others are in preparation for publication.

For studies on EMS-induced mutations of rapeseed, M3 seeds from over 200 lines of an EMS-induced mutation population were obtained. Some seed samples have been analyzed using NIRs for protein, oil, and glucosinolate contents, with the remaining analyses scheduled for 2025. DNA has been extracted from leaf samples collected from these lines. After assessment of the DNA quality some of them will be proceeded for genome sequencing analysis once the DNA quality is evaluated.

For the potato tuber research, the major evaluation of events for findings and publication will take place during 2025. The aim is to address competitive potato cultivation on northern latitudes, characterized by long days and a shorter permissive growing season. Additionally, the research seeks to identify strategies for controlling sink strength to optimize both starch quantity and starch structure in starch potato cultivars. Edits have been made, and events have been selected focusing

on identified lead genes in potato to study early tuberization, enhanced tuber sink development, faster maturation and improved daylength utilization. Furthermore, events aimed at altering starch loading in potato sink tissue, using targeted promoter insertions to enhance starch synthesis, are scheduled for a biotron study starting in January 2025.

In 2024, the high-yield seed wax ester (WE) production research was focused on the insufficient germination of genetically modified (GMO) seeds producing WE, likely due to improper oil body formation and disrupted ER organization. Kamil Demski, during his stay at the University of North Texas, designed experiments using transient expression in *Nicotiana benthamiana* leaves and confocal microscopy to address these issues (Fig. 7). He tested various gene combinations, incorporating jojoba lipid-droplet genes, and found that genes promoting wax ester production alone impaired

lipid droplet formation and ER organization. However, the addition of two jojoba genes, LDAP1 and LDIP, restored proper ER structure and improved lipid droplet uniformity. MALDI-TOF MS analysis further revealed that a fatty acid reductase and a wax synthase are keys in determining wax ester composition in the samples.

Our most significant recent findings reveal that the fundamental steps of autophagy have diversified across vascular and lower plants. In particular, we uncovered a key difference in the post-translational modifications of the core autophagy-related protein 8 (ATG8), which governs the catabolic activity of the autophagic pathway (Fig. 8). These insights provide a crucial understanding of how autophagy is adapted to different intracellular contexts in various plant lineages, and they offer promising avenues for fine-tuning plant autophagy to enhance overall plant fitness. A manuscript

detailing these results was recently accepted by Nature Communications. In addition, during her research visit to Dr. Kim Boutilier's lab at Wageningen University, the PhD student Florentine Ballhaus generated encouraging data suggesting that our identified autophagy modulators can improve microspore embryogenesis in *Brassica napus* (Fig. 9).

The results show that yields vary extensively between genotypes, environments, cuts and years. Similarly, forage quality varies between sites, with Umeå showing higher qualities of forage than the other two sites. We likewise observe a positive correlation between harvested forage yield and forage quality parameters in Umeå but not at the other two sites (Fig. 10).

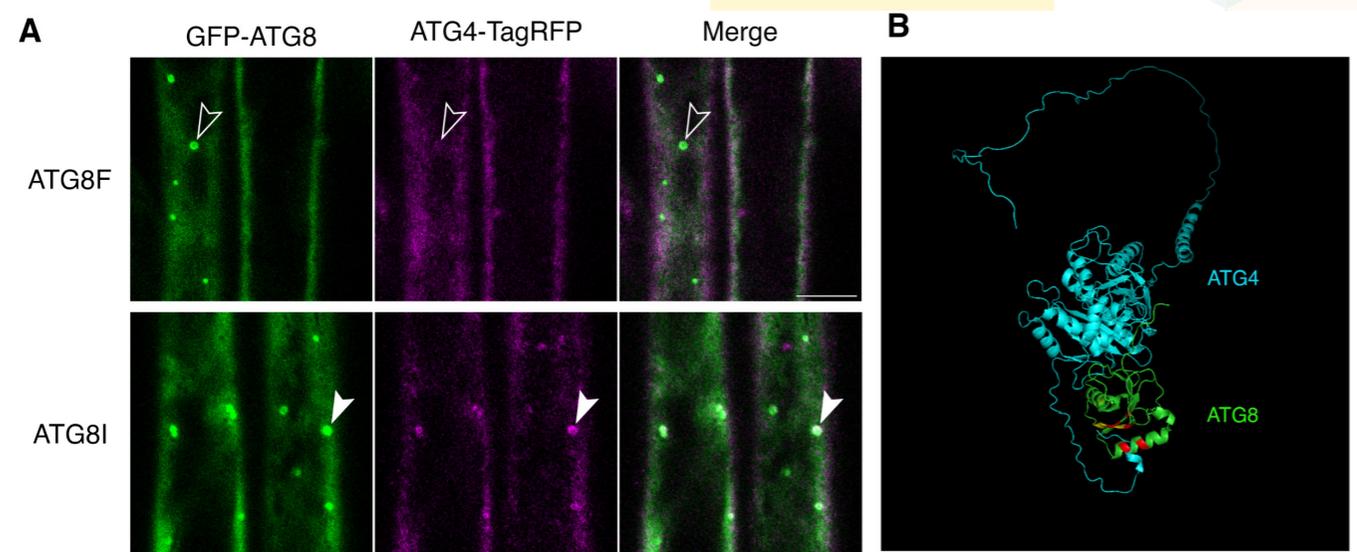


Fig. 8. Characterization of the protein-protein interactions critical to catabolic autophagy activity in plants. A. Confocal laser scanning microscopy images showing in planta co-localization of the autophagy-related protein 8 (isoforms ATG8I and ATG8F) with the dedicated protease ATG4, which is essential for the post-translational modification of ATG8. B. In silico prediction of the ATG4-ATG8F interaction interface using AlphaFold Multimer (Figure by Alyona Minina).

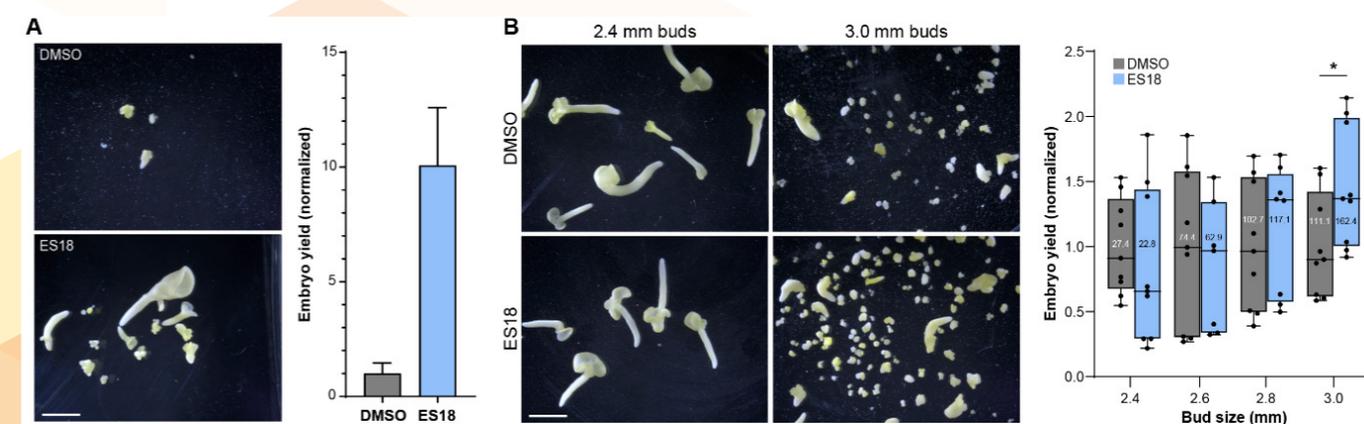


Fig. 9. Preliminary results of the effects of novel autophagy modulator endosidin 18 (ES18) on microspore embryogenesis (ME) in *Brassica napus* (canola cv. DH12075). (A) ES18 induces embryo development under no-heat shock + trichostatin A (TSA) conditions in bud sizes ranging from 2.4-3.0 mm in diameter. (B) ES18 increases embryo yields in samples derived from larger buds (3.0 mm diameter) under standard ME induction conditions (heat shock + TSA). Student's t-test, *P = 0.0323, n = 9 technical reps (3 independent experiments) (Figure by Alyona Minina).



Fig. 10 Left: Shoot development of Timothy. Right: Harvesting Timothy trials at Lantmännen in Svalöv (Photos by Girma Bedada Chala)

In what way the research has contributed to social benefit

Several projects within the C4F program are closely connected to, or have been transferred to, UDIs or EIPs. This serves as an effective way to translate program knowledge into product-based initiatives, ultimately benefiting society. Conversely, other projects demonstrate significant potential for long-term social benefits, contributing to societal well-being over time. Some key contributions of the C4F research to social benefit can be summarized as follows:

- Opportunities to produce proteins for food and feed locally from green biomass will have a direct and strong social impact. The impact will be increased additionally if side-streams can have additional uses e.g. as superabsorbent materials. The current use of petroleum based superabsorbents need to be changed into more sustainable solutions. Our work has the potential to end-up with more societal benefitting solutions.
- Due to climate change there is an urgent need to improve and develop new wheat varieties

with properties suitable to secure future food for the Swedish population and beyond. Thus, the determination of novel genes that can contribute in this aspect is necessary.

- The new knowledge on non-food legume protein materials and their suitability as future food. The potential of non-food legumes is big if selection of right pre-processing methods is made (functionality testing). For bio-fiber materials, new opportunities to create bio-based medical textiles from plants have been shown.
- The research on legume proteins for food uses promotes sustainable food innovations, transforming local crops into nutritious tempeh-like products. Public visibility was enhanced through features on SLU news, Vegomagasinet, and YouTube, highlighting the societal benefits of sustainable diets, local agriculture, and eco-friendly food systems.
- The research on starch aims to improve product quality in food as well as non-food applications. Our research on retrogradation can

in the long run reduce food waste by prolonging product shelf life. Good knowledge about the relationships between genetics, structure and properties is also vital for designing functional and sustainable materials that may be used in future food packages.

- The goal is to attain commercial levels of medium chain fatty acid as part of oil in Camelina. This would be a platform for a non-tropical source of lauric, myristic and palmitic fatty acids. A long term goal is to attain this in compliance with the suggested SDN-1 framework for NGT plants in EU.
- Novel CRISPR-edited or chemically induced mutant lines of oilseed crops with enhanced oil, protein, or seedcake qualities could, in the long run, significantly boost plant oil production. Additionally, these improvements would enable seedcake to serve as a high-value protein source for both food and feed, ultimately reducing reliance on fossil resources while promoting human health and environmental sustainability.
- The research carried out in this project has the potential to partially replace a market sector still reliant on fossil resources. Additionally, it could introduce a product with distinctive qualities similar to spermaceti oil, a lubricant whose production once threatened sperm whale populations.
- The short-term goal is to find mechanisms of importance to tuberization, starch yield and starch quality. The long-term goal is to utilize the findings to increase tuber and starch yields, as well as tailor starch quality for various applications.
- Our recent findings on ATG8-delipidation, published in Nature Communications, are poised to significantly influence strategies for modulating plant autophagy. In addition, the promising increase in microspore embryogenesis resulting from the application of our previously identified autophagy modulators suggests new opportunities to enhance

crop development and productivity.

- The end-goal is to supply information that can be used in breeding of novel varieties of Timothy and especially varieties that are useful for cultivation in northern Sweden.

At least one example on how C4F takes basic research to application to be used

The majority of the C4F projects are more orientated in applied research, in which we make our great efforts on transferring the knowledge obtained from basic research in oil, protein and starch as well as material science into potential food, feed and industrial applications in one way or another. Some examples are as followings:

- We try to understand underlying mechanisms that determines protein extractability in green leaf, which is basic science. The results will though be used for production of superabsorbent materials which is an application.
- Underlying molecular mechanisms behind important plant traits contribute to increased food security. The findings will thereafter be utilized by plant breeders to produce the coming wheat varieties which is an application.
- Characterization of properties of the starch/protein raw materials in biobased fiber production, a more basic nature of research, is necessary in order to successfully process those materials into fibers for targeted uses.
- Building on our group's previous research at SLU on faba bean proteins, starch properties, and physicochemical characteristics, we are now moving towards practical applications. This transition from basic research to product development is a crucial step in creating consumer-friendly and industrially viable products (Fig. 11).

- Characterization of the transcriptional network and enzymatic characterization for medium chain fatty acid synthesis in *Lindera* is of basic nature where findings are transferred in two steps to the oil crop *Camelina*, first by regular transformation and secondly by advanced CRISPR/Cas technology to comply with EU SDN-1 standards. We have started to fine tune gene expression and enzymatic activities within the framework of the *Camelina* genome with the goal to avoid insertion of foreign genes. The oil could then provide a temperate cultivation alternative to tropical deforestation for medium chain fatty acids.

- Identified target genes in model species or the same species from basic research have been used in improving target traits in oil crops by CRISPR/Cas9.

- The novel CRISPR genome editing principle along with optimized DNA-free CRISPR editing methods are used for trait improvement of the target crops, resulting in transgene-free "Category 1 plants", as suggested in a current legislative proposal on NGT plants from the EU commission.

- CRISPR/Cas9 edited plant material was studied for bio-material applications

- Examination of the biochemical and biophysical constraints of a crop plant system in effectively creating a new metabolic sink and applies this knowledge to the potential production of a valuable industrial product (a plant oil rich in wax esters, similar to spermaceti oil).

- A very efficient genome editing method is used to transfer the generated know how on improved earliness in potato, improved tuber sink development and faster maturation into commercial potato genotypes. The method will generate "Category 1 plants", suggested to be regulated as commercial bred crops in a current legislative proposal on NGT plants from the EU commission.

- Starch is a useful ingredient in a composite material where the starch can provide oxygen barrier functionality and something else gives strength and water resistance. Starch with increased amylose content has nutritional benefits since it has a higher proportion slow carbohydrates that potentially can decrease our insulin response and thereby reduce the risk of developing type II diabetes. Starch is an excellent food ingredient to control food texture and appearance with a wide range of properties and applications.

- We conducted a high-throughput drug screen in collaboration with the CBCS, and the resulting hits have been thoroughly characterized using an array of molecular biology, biochemistry, cell biology, and plant physiology assays. Within the C4F project, we are now evaluating the most promising candidates for their ability to enhance microspore embryogenesis in *Brassica*. This approach has the potential to expedite the acquisition of agriculturally desirable traits in this essential oil crop.



Vice program leader Li-Hua Zhu



Kamil Demski

Cracking the code of wax ester production in camelina plants

As a plant biologist and early-career researcher at C4F, Kamil Demski has spent the last few years focusing on wax esters. His goal is to develop an agricultural crop capable of producing these industry-important compounds, thereby reducing our reliance on fossil-derived sources.

“Up until now, the research aimed at accumulating wax esters in the seeds of genetically modified plants, has encountered some bottlenecks,” says Kamil Demski.

Kamil and his colleagues are working to address the challenge that, while they have successfully engineered agricultural plants to biosynthesise these highly desirable wax esters, the plants struggle to germinate and experience a decline in overall fitness.

To tackle the issue, Kamil is exploring three approaches.

In short, wax esters are compounds of fatty alcohols and fatty acids, but free fatty alcohols are harmful to plant health, potentially causing problems in Kamil’s plants.

“By introducing an additional enzymatic pathway, similar to one found in jojoba plants that breaks down free fatty alcohols, we hope to improve the germination and the fitness in our wax ester-producing camelina plants,” Kamil says.

These plants also have malformed lipid droplets in the seeds. Could this be the problem? Kamil is investigating whether specific proteins from jojoba can help the plants store wax esters within the lipid droplets more efficiently, and give the

droplets a normal shape.

His third approach examines the specific location of the wax ester accumulation within the different parts of the camelina seeds.

“We aim to direct the synthesis of wax esters to the cotyledons, rather than embryo, similar to what happens naturally in jojoba seeds,” Kamil explains.

The value of wax esters

Wax esters possess unique properties such as water resistance, lubricity, stability, and material compatibility. These qualities make them valuable in industrial applications, like lubricants for machinery, adhesives, sealants, polishes, and in products such as moisturisers, hair care, makeup, candles and paints.

“They have a wide range of industrial uses,” Kamil says.

Only a few plant species, like jojoba, naturally store wax esters in their seeds, but they can also be biosynthesised in genetically modified organisms.

Historically, wax esters were obtained from sperm whales, but this has largely ended due to whaling restrictions.

“For some applications, wax esters from whales were more advantageous than those from jojoba

because of chemical differences. Whale wax esters have shorter carbon chains, while jojoba’s are longer. We chose to develop camelina plants that form the shorter wax esters,” Kamil explains.

He adds, “If wax esters can be produced at large-scale in crops like camelina, it would provide a renewable, environmentally friendly source, offering a sustainable alternative to the fossil-based waxes used in industry.”

Academic journey and expertise

Kamil Demski moved to Sweden in 2020 for a postdoctoral position at SLU, after completing his bachelor’s and master’s degrees in biotechnology and molecular biology, followed by a PhD in biochemistry with a focus on plant biochemistry, at the University of Gdansk.

Throughout his academic career so far, he has specialised in lipids, with a particular interest in oil seed plants.

Looking ahead, he envisions a journey that combines both basic and applied research. He aims to continue studying how rare oils are biosynthesised in unusual plant species.

In his spare time, Kamil enjoys reading, playing video games, and staying active at the gym.

Author: Lisa Beste; Photo: Private



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Scientific publications

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11. Manikandan A, Muthusamy S, Wang ES, Ivarson E, Manickam S, Sivakami R, et al. Breeding and biotechnology approaches to enhance the nutritional quality of rapeseed byproducts for sustainable alternative protein sources- a critical review. *Front Plant Sci*. 2024;15:1468675.
12. Nynäs A-L, Berndtsson E, Newson WR, Hovmalm HP, Johansson E. Protein Fractionation of Leafy Green Biomass at the Pilot Scale: Partitioning and Type of Nitrogen in the Fractions and Their Usefulness for Food and Feed. *ACS Food Science & Technology*. 2024;4(1):126-38.
13. Ohlsson JA, Leong JX, Elander PH, Ballhaus F, Holla S, Dauphinee AN, et al. SPIRO - the automated Petri plate imaging platform designed by biologists, for biologists. *Plant J*. 2024;118(2):584-600.
14. Wulff-Vester A, Andersson M, Brurberg MB, Hofvander P, Alsheikh M, Harwood W, et al. Colour change in potato (*Solanum tuberosum* L.) tubers by disruption of the anthocyanin pathway via ribonucleoprotein complex delivery of the CRISPR/Cas9 system.
15. Zou Y, Ohlsson JA, Holla S, Sabljic I, Leong JX, Ballhaus F, et al. ATG8 delipidation is not universally critical for autophagy in plants.

Popular scientific publications (reports etc)

- Kuktaite, R, 2024. Plant product quality at SLU. Presentation at PlantLink meeting with Japanese scientific delegation at SLU, Alnarp, Augusti 30;
- Kuktaite, R, 2024. Plant Product Quality at SLU. Alnarp, September 3, meeting visitors from Plant Science and Resources from Okayama University, Japan.
- Langton, M. HealthFerm Consortium Meeting, 2024, "Fermentation of plant material of European origin for better texture, taste, and nutritional properties of TEMPEH-like foods," Consortium Meeting, Helsinki, Finland, September.

Hofvander, P. 2024-05-15, "Ett klipp för framtida livsmedelsgrödor- den nobelprisade "gensaxen" i praktiken", Rotary Helsingborg

Hofvander, P. 2024-06.26, "Gensaxen för ökad genetisk variation i växtförädlingen.", Borgeby fältdagar

Demski, K., Quach J., Whitehead P., Ding B.-J., Wang H.-L., Lager I., Chapman K.D., Löfstedt C., Hofvander P. 2024.

Scientific presentations

Andersson R. 2024. New starch for novel applications. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Ballhaus F. 2024. Chemical Modulation of Autophagy for Agricultural Application. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Chala G.B. 2024. Timothy forage quality across agro-climatic zones. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Demski K., Quach J., Whitehead P., Ding B.-J., Wang H.-L., Lager I., Chapman K.D., Löfstedt C., Hofvander P. 2024. Effective Wax Ester Production in Transgenic Crop Seeds Towards Fossil-Based Feedstock Replacement and Plant Protection from Insect-Pests. Poster presentation at Plant Biology, 2024. Honolulu, Hawaii, US. June 22-26.

Demski K., Quach J., Whitehead P., Ding B.-J., Wang H.-L., Lager I., Chapman K.D., Löfstedt C., Hofvander P. 2024. Towards Effective Production of Wax Esters with Medium-Chain Fatty Acyl and Fatty Alcohol Moieties in Seeds of Transgenic Crops. Short oral presentation at International Symposium on Plant Lipids, ISPL, 2024. Lincoln, Nebraska, US. July 14-19.

Demski K. 2024. Applying enzymatic machinery of jojoba lipid droplet formation in proper packaging of exogenous medium-chain wax esters in plants. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Diakité M.-S. 2024. Plant protein fractionation, products thereof and their feasibility: Superabsorbents biomaterials. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Fernandez Castaneda, L.A. 2024. Optimizing faba bean soaking and cooking time in the development of tempeh-

like products from faba bean. Poster presentation at Food Science Sweden Annual Conferences. Örebro, Sweden.

Fernandez A. 2024. Association of Sensory Properties and Volatile Compounds in Tempeh-Like Products. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Ingvarsson P. 2024. Deciphering the complex polyploid genomes and evolution of timothy grasses – *P. nodosum*, *P. alpinum* and *P. pratense*. Long-Read Sequencing Uppsala 2024. 21-23 October, 2024. Uppsala, Sweden.

González M. 2024. Genome editing on regulatory elements: enhancing starch quality in potato and fatty acid profile in *Camelina sativa*. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Johansson E, Yuzhou L, Yazdani M, Olalekan O, Ashraf R, Darlison J, Sahoo M, Kuktaite R, Chawade R, Muneer F, Shariatipour N, Rahmatov M 2024. Developing high quality, climate stable and resilient wheat through the introgressions of alien or ancient genes. 17th ICC international Cereal and Bread Congress. Nantes, France, 22-25 April.

Kanagarajan S. 2024. Significant reduction of glucosinolate levels in rapeseed mutants generated by CRISPR editing. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Moss O. and Zhu L.-H. 2024. Improving the seedcake quality of rapeseed by using RNP-mediated CRISPR gene editing. Poster presentation at 26th International Symposium on Plant Lipids (ISPL2024) in Lincoln, Nebraska, USA. 14-19 July.

Muneer F. 2024. Processing of pea bean proteins for improved functional performance in food applications. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Olalekan O, Darlison J, Bajgain P, Rahmatov M. 2024. Nutritious Wheat For Healthy Diet: Genetic Exploration Of Ancient And Alien Germplasm. Oral presentation. 21st European Young Cereal Scientists and Technologists Workshop, Lisbon, Portugal, 3-5, June.

Olalekan O, Darlison J, Shariatipour N, Gerhardt K, Odilbekov F, Henriksson T, Björklund T, Wendin K, Rahmatov M, Johansson E. 2024. Searching Unique Qualities from Old and Alien Cereals for Use in Conventional and Organic

Towards Fossil-Based Feedstock Replacement and Plant Protection from Insect-Pests. Poster presentation at BDI Expo, University of North Texas. Denton, Texas, US. May 15.

Demski, K. 2024. Applying enzymatic machinery of jojoba lipid droplet formation in proper packaging of exogenous medium-chain wax esters in plants. Presentation at the C4F Workshop 2024. Lund, Sweden. December 9th.

Mariette, E. A. 2024-01-24 "NGT-are they accessible or not" Bryssels.

Minina, E. A. 2024-12-16. Evolutionary Diversification of the Core Autophagy Machinery in Plants Webinar/ Plant membrane seminars. Zoom. Invited speaker.

Minina, E. A. 2024-11-28. Diversification of the Core Autophagy Machinery in Plant Evolution and Cell Differentiation. VIB seminar, Ghent, Belgium. Invited speaker.

Minina, E. A. 2024-09-12/17. The Evolution of the ATG4 Protease Role in Autophagy IPPC, Vienna, Austria., Invited speaker.

Ballhaus, F. 2024. Oral presentation "ATG8-delipidation is not universally critical for autophagy in plants" at NAS, Iceland. Aug. 28-30.

Minina, E. A. 2024. The evolution of the ATG4 protease role in autophagy. Oral presentation at Metacaspase Workshop, KAW, Sigtuna, Sweden, 28 Aug.

Minina, E. A. and Ballhaus, F. 2024. Oral presentation "Evolution and modulation of plant autophagy" at Minisymposium. Uppsala, Sweden. 25 May.

Interviews and presence in media

Fernandez Castaneda L.A, Fava bean in transformation - becoming the food of the future in SLU's lab <https://internt.slu.se/en/news-originals/2024/11/tempeh/> SLU News, November 2024.

Hållbara livsmedel: Möt SLU-forskaren Alejandra Castaneda <https://supermiljobloggen.se/nyheter/intervju/hallbara-livsmedel-mot-slu-forskaren-alejandra-castaneda/> blog news, November 2024.

Forskare vid SLU förvandlar bondbönor till framtidens mat <https://vegomagasinet.se/forskare-vid-slu-forvandlar-bondbonor-till-framtidens-mat/> article in online news November 2024.

Zhu, L.-H. 2024. Intervju från Sverigesradio Ekot: Raps är framtidens mat – kan ersätta soja. Juni 9.

Breeding. Poster presentation. Nordic Conference on Genetic Resources: Possibilities and Urgency, Malmö, Sweden, 11th, December.

Olalekan O. 2024. Unlocking the Potential of Ancient and Alien Wheat: A path to Superior Food Satisfaction in Modern breeding Nutritionally Important Traits. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Singh K.S., Muneer F., Kocherbitov, V., Kuktaite R. 2024. Compatibility, microstructure and thermodynamical properties of gliadin nanofibers electrospun with cinnamaldehyde and cellulose. Oral presentation at the International Symposium on Fiber Science and Technology, November 25-28th, Kyoto, Japan.

Singh S. K. 2024. Electrospun Gliadin Nanofibers for Medical Textile Applications. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Zhu L.-H. 2024. Genome editing of rapeseed for reducing sinapine and phytic acid contents. Oral presentation at C4F-Workshop, 7th of Dec, Lund.

Collaboration with industry or other parts of society

- Bio Gaia
- Chalmers University
- Copenhagen University
- DLF Beet Seed AB
- ETH Zurich
- Findus
- FoodHills
- Gasum
- Gropro
- Gunnarshögs Gård AB
- Grönsaksmästarna
- Havredals Biodevelop AB
- Helsinki University
- ICA
- ISCA Technologies
- Kalmar Ölands Trädgårdsprodukter
- KTH

- Lantmännen
- Lilla Harrie Valskvarn
- Lund University
- Lyckeby Stärkelse AB
- MAX Hamburgare
- Nelson Seed
- Oriflame
- Orkla
- Planta LLC
- Region Skåne
- RISE
- SLU Grogrund (A number of research projects connected to the C4F program)
- Sveriges Stärkelseproducenter Förening
- Syngenta
- University of Turku
- Uppsala University
- VVT
- Örebro University

Other funding that has been received partially or fully due to the TC4F research

Co-funding are from SLU-Grogrund, Novo Nordic Foundation, Formas, VR, Carl Tryggers Stiftelse and EPIC-XS, LTV (SLU), Vinnova, EU, Fysiografen (Nilsson-Ehle Foundation?), Erik Philip-Sörensens stiftelse, etc.

Education

a) PhD theses, MSc theses, Bachelor theses

Jayarathna, Shishanthi (Female) 2024. Doctoral thesis: Novel starch types - Molecular diversity for future applications. Swedish University of Agricultural Sciences. Acta Universitatis Agriculturae Sueciae 2024:42. ISBN 978-91-8046-256-3

Lan, Yuzhou (Male). 2024. Doctoral thesis. Exploring the genetic toolbox for climate-resilient spring wheat. Acta Universitatis Agriculturae Sueciae, 2024: 47. ISBN: 978-91-8046-034-7, eISBN: 987-91-8046-035-4. Swedish University of Agricultural Sciences.

Olalekan, O.J., 2024. Introductory paper. Exploring Ancient and Alien Cereal Germplasms to Advance Sustainable Wheat Breeding for Enhanced Functional, Nutritional, and Sensory

Quality. Introductory paper at the Faculty of Landscape Architecture, Horticulture and Crop Production Science (2024: 4).

Yousef Rahimi (Male), "Phenotypic and genetic diversity in wild and domesticated timothy and related Phleum species: implications for breeding. Acta Universitatis Agriculturae Sueciae, 2024:32. ISBN: 978-91-8046-328-7. Swedish University of Agricultural Sciences.

Silvana Moreno (Female), 2024. Doctoral thesis: Responses to waterlogging and drought of timothy and related Phleum species: phenotype and transcriptome diversity. Acta Universitatis Agriculturae Sueciae, 2024: 29. ISBN: 978-91-8046-322-5. Swedish University of Agricultural Sciences.

Anandhavalli Manikandan (Female), 2024. Master thesis: Genetic insights into glucosinolate metabolism: A study of oilseed rape (Brassica napus L.) transporter knockout mutants across developmental stages.

b) Supervision and teaching (include supervision of finished and on-going students, include teaching and organization of courses)

Kuktaite, Ramune. Main supervisor for Lic-candidate Singh, Sanjit. Tentative title: Gliadin and CRISPCas9 potato starch innovative fiber materials; Expected date for dissertation: 14 th November, 2025.

Kuktaite, Ramune. Co-supervisor for PhD-candidate Yuzhou, Lan. Thesis title: Exploring the genetic toolbox for climate-resilient spring wheat: Drought impact on yield, breadmaking quality, nutritional value and toxicity. Defended on 2024-05-31.

Fernandez Castaneda, L.A. Lab supervisor at the course Food Chemistry and Food Physics (LVO110), 15 ECTS, Ultuna

Zamaratskaia G. Teaching in the courses: "Biochemistry", "Animal Food Science", "Food Chemistry and Food Physics", "Human physiology and nutrition", "How to write and publish scientific article in molecular sciences", "To communicate science", course leader of "Advanced human nutrition".

Ida Lager, Kamil Demski: Co-supervisors for Ke Xu, ongoing (Main Supervisor: Lizel Potgieter): Elucidation of jojoba gene expression in the cotyledon and hypocotyl during seed germination. SLU, Alnarp. 2024-2025.

Mariette Andersson: Supervisor for Master project Haripriyaa Arani Suresh, ongoing.

Mariette Andersson: Supervisor for a new PhD student Lubos Riha, started late 2024.

Roger Andersson. Main supervisor for PhD-candidate Shishanthi Jayarathna. Tentative title: New starch for novel applications.

Roger Andersson. Course organizer and teaching at the course "Plant food science", (LV0113), 15 ECTS, SLU.

Minina, Alyona. Main supervisor for PhD-candidate Ballhaus Florentine. Tentative title: Membrane-bound and membraneless organelles in plant stress response. Expected date for dissertation: September 2026.

Minina, Alyona. Teaching and organizing of a PhD course in qPCR (course ID P000008): <https://www.alyonaminina.org/2024-qpcr-course>

Minina, Alyona and Florentine Ballhaus. Teaching of the Biochemistry course for undergraduates (course ID KE0073 30086)

Zhu, Li-Hua. Supervisor for PhD candidate Oliver Moss. Tentative title: Improvement of seedcake quality of rapeseed for high quality food and food uses. Expected date for dissertation: 2025.

Kanagarajan, Selvaraju. Co-supervisor for PhD candidate Oliver Moss. Tentative title: Improvement of seedcake quality of rapeseed for high quality food and food uses. Expected date for dissertation: 2025.

Hofvander, Per. Teaching at the course "Applied Plant Biotechnology" (BI1344), Alnarp.

Hofvander, Per. Teaching at the course "Sustainable plant production" (BI1295), Alnarp

Andersson, Mariette. Teaching at the course "Advanced plant breeding and genetic resources" (BI1345), Alnarp.

Lager, Ida. Course leader and teaching at the course "Växterns kemi och biokemi" (KE0070), Alnarp

Zhu, Li-Hua. Course organiser and teaching at the course "Advanced Plant Breeding and Genetic Resources" (BI1345), Alnarp

Zhu, Li-Hua. Course organiser and teaching at the course "Applied Plant Biotechnology" (BI1344), Alnarp.

Grimberg, Åsa. Teaching at the course "Växterns kemi och biokemi" (KE0070), Alnarp.

Andersson, Mariette. Teaching at the course "Advanced plant breeding and genetic resources" (BI1345), Alnarp.

Lager, Ida. Course leader and teaching at the course "Växterns kemi och biokemi" (KE0070), Alnarp

Zhu, Li-Hua. Course organiser and teaching at the course "Advanced Plant Breeding and Genetic Resources" (BI1345), Alnarp

Zhu, Li-Hua. Course organiser and teaching at the course "Applied Plant Biotechnology" (BI1344), Alnarp.

Alyona Minina. Main supervisor for PhD-candidate Holla, Sanjana. Tentative title: Revealing the dynamics of plant autophagy. Expected date for dissertation: September 2023.

Alyona Minina. Main supervisor for PhD-candidate Ballhaus Florentine. Tentative title: Membrane-bound and membraneless organelles in plant stress response. Expected date for dissertation: September 2026.

Alyona Minina. Main supervisor for project student Kjelstrom, Jarl. Title: Use of Fungal bioluminescence pathway as a reporter for plant autophagy. 15 ECTS.

Alyona Minina. Lecture on advanced microscopy methods for the Masters degree course at Uppsala University "Genetic and Molecular Plant Science" (15 ECTS), September-October 2022

Alyona Minina. Organizer and teacher of the qPCR course (3.5 HEC, P000008 F0027) for the Organism Biology PhD School. SLU, Uppsala. November-December 2022

Florentine Ballhaus. Lab and seminar teacher for the Masters degree course at Uppsala University "Genetic and Molecular Plant Science" (15 ECTS), September-October 2022

C4F- Crops for the Future, Personnel

Name	Position	Part of full time financed by TC4F			
Eva Johansson	Professor	15%	Neha Salaria	Postdoc	30%
Li-Hua Zhu	Professor	10%	Maya-Setan Diakité	Postdoc	50%
Maud Langton	Professor	0	Florentine Ballhaus	PhD-student	35%
Roger Andersson	Professor	0	Anna-Lovisa Nynäs	PhD-student	50%
Volkmar Passoth	Professor	0	Oliver Moss	PhD-student	50%
Pär Ingvarsson	Professor	0	Alejandra Castaneda	PhD-student	50%
Thomas Prade	Docent	0	Lubos Riha	PhD-student	50%
Galia Zamaratskaia	Researcher	0	Olawale Olalekan	PhD-student	0
Mariette Andersson	Researcher	0	Sanjana Holla	PhD-student	0
Ramune Kuktaite	Researcher	0	Shishanthi Jayarathna	PhD-student	50%
Su Lin Hedén	Research	0	Lan Yuzhou	PhD-student	50%
Mahubjon Rahmatov	Researcher	0	Sanjit Kumar Sing	PhD-student	0
Bill Newson	Researcher	0	Anandhavalli Manikandan	Msc-student	0
Ida Lager	Researcher	0	Judy Quach	Msc-student	0
Selvaraju Kanagarajan	Researcher	16%	Ke Xu	Msc-student	0
Alyona Minina	Researcher	35%	Emelie Ivarson	Research eng.	50%
Per Hofvander	Researcher	0	Eu Sheng Wang	Research eng.	40%
Girma Bedada Chala	Researcher	25%	Lizel Potgieter	Bioinformatition	0
Adrian Dauphinee	Researcher	0	Mirela Beganovic	Research ass.	0
Matías González	Postdoc	30%	Josefin Alverup	Research ass.	0
Faraz Muneer	Postdoc	50%	Xueyuan Li	Research ass.	0
Kamil Demski	Postdoc	30%			
Shrikant Sharma	Postdoc	0			

*Researchers listed with 0% have received financing from TC4F earlier which resulted in projects with independent financing.

TC4F Economy 2024

In 2024, TC4F received 30,1 mio SEK of funding which were distributed according to the budget of which 109% were used. The deficit was caused by spending money that had accumulated due to delays in recruitment due to the Covid-19 pandemic.

	SLU	UmU	Skogforsk	Total
Distributed Funds (tkr)				
Coordination	1 045			1 045
Plant Physiology (UMU)		5100		5 100
Forest Genetics and Plant Physiology	5 902			5 902
Southern Swedish Forest	4 715			4 715
Forest Ecology and Management	3 655			3 655
Forest Mycology and Plant Pathology	1 050			1 050
Skogforsk			1 100	1 100
C4F (LTV)	7 522			7 522
TOTAL	23 889	5 100	1 100	30 089
Costs, spent funds (tkr)				
Coordination	1716			1 716
Plant Physiology (UMU)		5100		5100
Forest Genetics and Plant Physiology	7 850			7 850
Southern Swedish Forest	3 984			3 984
Forest Ecology and Management	4 188			4 188
Wildlife, Fish and Environmental Studies	197			197
Forest Mycology and Plant Pathology	945			945
Skogforsk			1 100	1100
C4F (LTV)	7 762			7 833
Total	26 641	5100	1 100	32 841
RESULT T4F	-2 512	0	0	
RESULT C4F	-240			
Total RESULT	-2 752	0	0	- 2 752

*assigned postdoc grants

