



# TC4F ANNUAL REPORT 2015

## TREES AND CROPS FOR THE FUTURE

Trees and Crops for the Future – TC4F – develops knowledge on sustainable plant production and plant based product development within agricultural and boreal forest systems with the main objective to support the development of a new circular bioeconomy in Sweden.

Cover photo:  
Julio Gonzalez, SLU

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## Svensk sammanfattning

### Trees and Crops for the Future – TC4F

TC4F utvecklar kunskap om hållbar växtproduktion och produktutveckling från växter med det övergripande syftet att stödja utvecklingen av Sveriges cirkulära bioekonomi. TC4F handlar om både agrara och skogliga odlingssystem och länkar samman grundforskning om växtmolekylärbioologi, växtfysiologi och genetik med tillämpbar forskning om skogsskötsel och växtprodukter. TC4F startade 2010 som ett samarbete mellan SLU, Umeå universitet och Skogforsk. Inom SLU spänner samarbetet över tre fakulteter: fakulteten för skogsvetenskap, fakulteten för landskapsarkitektur, trädgårds- och växtproduktionsvetenskap samt fakulteten för naturresurser och jordbruksvetenskap. TC4F gör samhällsnytta tack vare en hög ambition att samverka med den areella sektorn.

### Bakgrund

TC4F är utsett till ett strategiskt forskningsområde för Sverige. Bakgrunden är att i forskningspropositionen för 2008 beslutade dåvarande regering att tillföra nya basresurser för forskning till Sveriges lärosäten. Man beslutade att göra detta i form av en satsning på strategiska forskningsområden (SFO:n). Därmed utlystes medel som Sveriges lärosäten kunde söka inom 20 strategiska forskningsområden. I varje ansökan skulle ett lärosäte fungera som huvudsökande och ansökan skulle göras i samarbete med ett eller flera andra lärosäten som då fungerade som medsökande. Utlysningen gjordes i januari 2009 med sista ansökningsdag i mitten på mars samma år och ansökningarna skulle skickas till de olika forskningsråden som satts att ansvara för de strategiska forskningsområdena. På SLU beslutade Rektor i samråd med ledningen att SLU skulle gå in som huvudsökande på två SFO:n och som medsökande i ytterligare en handfull ansökningar. Positivt utfall kom för SLUs del i form av TC4F som huvudsökande och som medsökande i form av Bio4Energy (huvudsökande Umeå universitet) och Stand-up for Energy (huvudsökande Uppsala universitet). Totalt erhöll 43 starka forskningsmiljöer medel i form av SFO-satsningar. Medel från regeringen för SFO-satsningarna kom i första hand i form av en femårig satsning. Redan vid utlysningen aviserade regeringen att en utvärdering skulle göras efter fem år och beroende på utgången av denna skulle dessa medel kunna komma att permanentas. I utvärderingen som genomfördes 2015 av internationella utvärderingspaneler bedömdes vissa lärosäten som mycket framgångsrika i hur de bedrivit sina SFO och de erhöll därmed ett större basanslag för sina SFO från 2016 och framåt. Några lärosäten ansågs mindre framgångsrika och erhöll därmed nedskärningar i sina basanslag. Flertalet lärosäten erhöll bra omdömen och fick behålla sina basanslag för SFO. SLU bedömdes framgångsrikt ha bedrivit verksamheten i TC4F och fick därmed behålla sitt basanslag för detta SFO.

### En viktig framtidssatsning vid SLU, Umeå universitet och Skogforsk

Ett huvudsakligt syfte för regeringen med SFO-satsningen var att den skulle öka Sveriges konkurrenskraft. Vid utvärderingen 2015 bedömdes TC4F vara ett SFO med fortsatt stor vikt för Sveriges konkurrenskraft. Dessutom bedömdes TC4F hålla mycket hög kvalitet. Verksamheten inom TC4F spänner över både grundläggande och tillämpade frågeställningar inom både agrara och skogliga odlingssystem. Förutom att TC4F producerar vetenskap av hög kvalitet så fungerar TC4F som en plattform för samverkan mellan forskare från olika

grundläggande och tillämpade discipliner. TC4F är även integrerat i andra stora forskningsprogram, som Berzelii Centre for Biotechnology, Future Forests, ICON och Framtidens Oljeväxter. Tack vare denna integrerade verksamhet har TC4F effektivt nått ut med resultat till den areella samhällssektorns aktörer. TC4F har bidragit till att SLU, Umeå universitet och Skogforsk har kunnat profilera sig som starka, framgångsrika och framåtsyftande forskningsaktörer inom växtforskningen i Sverige och i världen.

### TC4F verkar för;

- Att göra SLU, Umeå universitet och Skogforsk internationellt synligt genom bra forskning och starka publikationer. Under 2015 publicerades totalt 67 publikationer från programmet, varav 3 i Nature och ett stort antal i tidskrifter med hög impact factor (IF>5).
- Att utbilda framtidens forskare. Under 2015 finansierades totalt 15 doktorander och 5 post-docs från programmet. Totalt 10 doktorander med finansiering från programmet disputerade under 2015.
- Att sprida kunskap till samhällets aktörer inom växtforskningsområdet samt till studenter. Programmets deltagare bidrar aktivt och i hög grad i samhällssamverkan, forskningssamverkan nationellt och internationellt och i undervisning.

### Forskningsgenombrott

- Skapande av en databas – PlantGenIE – innehållande information om olika växtgener. Denna databas kommer att bli mycket användbar för växtforskare för att hitta och förstå närvaron av olika gener i växter och deras funktioner.
- CRISPR/Cas9 (den nya gensaxen) har slagit igenom och använts framgångsrikt både i träd och andra grödor av forskare inom TC4F. Denna teknik kommer att bli användbar inom många delar av programmet.
- Ny kunskap om hur trädets allokering påverkas av kvävegödsling kommer att kunna förändra hur storskalig skogsgödsling utförs i det praktiska skogsbruket.
- Upptäckten om att stam-respiration varierar med trädhöjden kommer att påverka all framtida forskning som rör tillväxt hos träd, trädrespiration och frisättning av CO<sub>2</sub> från träd.
- Ny kunskap om varför contortatall i Sverige växer bättre än contortatall i Nordamerika kommer att kunna påverka skogsbrukets framtida användning av trädslag som inte är inhemska för Sverige.
- Blandskog producerar inte mer volym än monokulturer men kan med rätt skogsskötsel generera fler ekosystemtjänster.
- Upptäckten om att växtproteiner som har skummats har förmåga att ta upp vatten i lika hög grad som konventionella petroleumbaserade superabsorbenter kommer att bilda bas för fortsatta studier gällande applikationer hos växtbaserade material med superabsorberande förmåga, som t ex. blöjor.
- En ny ris-sort genererades som innehåller en ny transkriptionsfaktor som bidrar till en allokering av biomassa ovan jord istället för i rötterna. Denna omallokering av biomassa till ovanjordiska delar genererade också en lägre metangasavgivning från riset och en ökning av avkastningen.

## Samhällsnytta

- Skogsträdförädling som leder fram till produktion av skogsplantor med egenskaper som bidrar till hållbar skogstillväxt i ett klimat under förändring.
- Utvecklingen av den nya ris-sorten SUSIBA leder till mer uthållig risproduktion i världen.
- Ett nytt samarbete har etablerats med SCA och Lantmännen för att utveckla biologiska superabsorbenter.
- Programmets forskare har varit ledande inom diskussioner i olika forum gällande möjligheterna och effekterna av CRISPR/Cas9.

## Ekonomi

TC4F har under programmets första fas 2010-2015 haft en total budget på 133,7 miljoner kronor. Budgeterade kostnader för programmets aktiviteter under 2015 var 26,6 miljoner kronor och använda medel uppgick den 31 december 2015 till 28,2 miljoner kronor, ett resultat nära budgeten. Differensen täcks av ej förbrukade medel från tidigare år.

Totalsammanställningen av ekonomin för programperioden är godkänd av programstyrelsen per capsulam.

## Summary

### Trees and Crops for the Future – TC4F

TC4F develops knowledge on sustainable plant production and plant based product development with the main objective to support the development of the new circular bioeconomy in Sweden. TC4F includes research in agricultural as well as forestry systems linking basic research on plant molecular biology, plant physiology and genetics to applied research on silviculture and plant based products. TC4F started in 2010 as a collaboration between The Swedish University of Agricultural Sciences (SLU), Umeå University (UmU) and the Forestry Research Institute (Skogforsk). Within SLU the collaboration includes three faculties; the faculty of forest sciences, the faculty of landscape architecture, horticulture and crop production science, and the faculty of natural resources and agricultural sciences. TC4F has high ambitions to provide social benefit through interaction with the agricultural and forestry sector.

### Background

TC4F is appointed as a strategic research area (SRA) for the Swedish society by the government. The background is that in the Swedish Research Bill (2008) the former government resolved to provide funding for research at Swedish universities in certain SRA's. Twenty SRA's were identified. The calls for proposals were made in January 2009 and the closing date was in mid-March the same year. Each application should have a main applicant and should be made in cooperation with one co-applicant or more. The Vice Chancellor at SLU together with the management group decided that SLU would apply to two SRA's as main applicant and as co-applicant to an additional number of SRA's. SLU were successful in three applications; TC4F as the main applicant, Bio4Energy as co-applicant (main applicant UmU) and Stand-up for Energy as co-applicant (main applicant Uppsala University). In total, 43 strategic research environments received funding for an initial period of five years. The government announced in the call that an evaluation would be made after these initial five years and depending on the outcome, the funding could be made permanent. The evaluation was conducted by an international evaluation committee in 2015, in which SLU was considered to have successfully conducted research within TC4F. Thus, TC4F retained their funding for this SRA.

### An important investment in future research for SLU, Umeå University and Skogforsk

One of the government's main purposes with the SRA-initiative was to increase Sweden's competitiveness internationally. The evaluation in 2015 showed that TC4F was an SRA of great importance for Sweden's competitiveness. Moreover, the research produced within TC4F was considered to be of very high quality. The research within TC4F includes both basic and applied research in agricultural as well as forestry systems. In addition, TC4F serves as a platform for collaboration between scientists from different basic and applied research disciplines. TC4F is also integrated in other successful research programs such as Berzelii Centre for Biotechnology, Future Forests, ICON and Framtidens oljeväxter. As a result of this integration, TC4F has efficiently reached out with research results to actors within the agricultural and forestry sector. Research advances within TC4F has also contributed to that SLU, UmU and the Forestry Research Institute can profile themselves as strong, successful and future oriented research environments within plant science in Sweden and in the world.



### TC4F acts to;

- Make SLU, Umeå University and the Forestry Research Institute internationally visible through good research and strong publications. In 2015 TC4F published 67 scientific articles in international journals, of which 3 in Nature and a large number of articles in journals with high impact factor (IF > 5).
- Educate future scientists. In 2015 TC4F financed 15 PhD students and 5 post-docs. Ten PhD students with funding from the program defended their doctoral theses in 2015.
- Disseminate knowledge to actors in the society within the area of plant research as well as to students. TC4F's researchers contribute to a high degree to integration with societal actors, with other national and international researchers and with students.

### Research advances

- Construction of a database - PlantGenIE - containing information on various plant genes. This database will be very useful for researchers to locate and understand the presence and functions of different genes in plants.
- CRISPR/Cas9 (the genome editing tool) has made a breakthrough and has been used successfully in trees and other plants by the researchers in TC4F. This technique will be useful in many parts of the program.
- New knowledge about how allocation in forest trees is affected by nitrogen fertilization will possibly change the way large-scale forest fertilization is performed in practical forestry.
- The discovery that stem respiration varies with tree height will affect all future research related to forest tree growth, tree respiration and release of CO<sub>2</sub> from trees.
- New knowledge about why lodgepole pine in Sweden is growing better than in North America may influence the future use of non-native tree species in Swedish forestry.
- Mixed forest does not produce more volume than monocultures, but generate more ecosystem services if managed properly.
- The discovery that foamed plant proteins can absorb water to a similar degree as conventional petroleum-based super absorbents will lead to further studies regarding possible application areas for super absorbing plant-based materials, i.e. diapers.
- A new variety of rice was generated containing a transcription factor which contributes to enhanced biomass allocation to above ground parts. Moreover, this reallocation of biomass led to increased yield and lowered methane emissions.

### Social benefits

- Forest tree breeding that leads to the production of forest plants with characteristics that contribute to sustainable forest growth in a changing climate.
- Development of the new rice variety SUSIBA contributes to a more sustainable rice production worldwide.
- A partnership has been established between TC4F, SCA and Lantmännen to develop plant based super absorbents.
- The program's researchers have been leading the discussions in various forums regarding the new possibilities and effects of the genome editing tool CRISPR/Cas9.

## Economy

TC4F has during the initial program period 2010-2015 had a total budget of 133.7 million SEK.

The budget for program activities during 2015 was 26.6 million SEK and expenses by December 31<sup>st</sup> were 28.2 million SEK, a result close to the budget. The difference will be covered by unused funds from previous years. The overall compilation of the economy for the program period has been approved by the Program Board.

## Theme 1 – Forest genetics and next generation of forest trees

Theme 1 is devoted to basic science on genetics, genomics and natural variation in trees, and its application to develop better genetic material for Swedish forestry. The focus is on *Populus* species (aspen and poplars) and Norway spruce. The research of TC4F at UPSC and together with the Berzelii Centre is unique as it connects world-leading research on tree genomics and tree biotechnology with the operational tree breeding at Skogforsk. Theme 1 contribute to the development of genomic tools for *Populus* and conifers, including full genome sequences, gene expression catalogues and genome databases (PopGenIE, ConGenIE and PlantGenIE), research that is also funded in particular by KAW. Theme 1 is also studying natural variation in tree populations using both UPSCs collections of natural accessions of aspens and Skogforsks huge resource of trees in the Swedish spruce breeding program.

### Main findings in 2015

During 2015 we have, for example, followed up the work on *Populus* and Norway spruce genomics and developed our bioinformatic tools and created a database, PlantGenIE (Sundell et al. 2015), a useful tool for mining genomics data not only from *Populus* and Spruce but also from *Arabidopsis*, as well as a resource for analysis of transcription factors (Liu et al. 2015). The UPSC Bioinformatics facility has also been established, in part by TC4F funding. We have used high-throughput RNAsequencing (metagenomics) to analyse the fungal community associated with Norway spruce (Delhomme et al. 2015), but also studied the fungal community associated with for example aspen (Blumenstein et al. 2015). Moreover, we have studied the interaction between aspen leaf chemistry, nutrient status and herbivores (Bandau et al. 2015, Robinson et al. 2015). We have also carried on the “systems genetics” work in aspen, for example completing eQTL mapping (Terebieniec et al. in preparation).

Furthermore, we have used genomic tools to study classical forest genetic questions like pollen contamination in seed orchards (Funda et al. 2015), inbreeding and genetic variation (Garcia-Gil et al. 2015), population genetics (Pan et al. 2015), future climate change (Hu et al. 2015), horizontal gene transfer (Wang et al. 2015) and hybridization (Meng et al. 2015) in conifers and have found that there is a variation in pine weevil susceptibility in the Swedish spruce breeding population (Björklund et al. in preparation). We have also found that recombination rate shape pattern of polymorphism in *Populus* (Wang et al. 2015).

We have also continued our studies on aspen phenology and growth, and described the role of many candidate genes (LHY, EBI, CCA, GI, GIL etc.) regulating phenology traits through detailed studies under control conditions, and also made a successful scoring of the largest GM tree field experiment in Europe, established in 2014 with TC4F funding, where trees affected in the expression of these and other candidate genes regulating phenology and established which genes that regulate certain phenology traits.

Finally, we have continued to develop the spruce somatic embryogenesis (SE) systems in conifers, Skogforsk has also raised 2500 SE emblings, in parallel to rooted cuttings, for field trial testing of elite spruce lines for northern Sweden. We have also worked on with the spruce transformation system, established genome editing through CRISPR/Cas9 in both *Arabidopsis* and *Populus* and contributed to the political debate concerning CRISPR/Cas9 and the GMO-definition of EU.

## Personnel involved in Theme 1 in 2015

Name	Gender and position	Part of full time financed by TC4F
Stefan Jansson	M, Professor	0
Ove Nilsson	M, Professor	0
Bengt Andersson Gull	M, Professor	20
Tomas Moritz	M, Professor	0
Tim Mullin	M, Professor	7.5
Maria Eriksson	F, Researcher	50
Benedicte Albrechtsen	F, Researcher	50
Kathryn Robinson	F, Researcher	75
Johan Westin	M, Researcher	25
Sara Abrahamsson	F, Researcher	5
Nathaniel Street	M, Assistant Professor	80
Junko Takahashi	F, Research Engineer	50
Xiao-Ru Wang	F, Professor	0
Barbara Terebieniec	F, PhD student	80
Alexis Sullivan	F, PhD student	0

## Scientific publications

During 2015 Theme 1 has published 26 peer reviewed scientific articles financed by TC4F. Authors marked in bold represents researchers that have been financed by, or are associated to, the research program.

- Bandau F, Decker V.H.G., **Gundale M.J**, **Albrechtsen B.R.** 2015. *Genotypic tannin levels in Populus tremula impact the way nitrogen enrichment affects growth and allocation responses for some traits and not for others*. PLoS ONE, 10(10): e0140971.
- Benson S.L., Maheswaran, P., Ware, M.A., Hunter, C.N., Horton, P., **Jansson, S.**, Ruban, A.V., Johnson, M.P. 2015. *An intact light harvesting complex I antenna system is required for complete state transitions in Arabidopsis*. Nature Plants 1, Art no: 15176 (2015) doi: 10.1038/nplants.2015.176.
- Blumenstein, K., Macaya-Sanz, D., Martín, J.A., **Albrechtsen, B.R.**, Witzell, J. 2015. *Phenotype MicroArrays as a complementary tool to next generation sequencing for characterization of tree endophytes*. Front. Microbiol., 6: 1033.
- Blumenstein, K., **Albrechtsen, B.R.**, Martín, J.A., Hultberg, M., Sieber, T.N., Helander, M., Witzell, J. 2015. *Nutritional niche overlap potentiates the use of endophytes in biocontrol of a tree disease*. BioControl, 60(5): 655-667.
- Eriksson, M.E.**, Hoffman, D., Kaduk, M., Mauriat, M., Moritz, T. 2015. *Transgenic hybrid aspen trees with increased gibberellin (GA) levels suggest that GA acts in parallel with FLOWERING LOCUS T2 to control shoot elongation*. New Phytologist, 205: 1288-1295.
- Delhomme, N., Sundström, G., Zamani, N., Lantz, H., Lin, Y.C., Hvidsten, T.R., Höppner, M.P., Jern, P., Van de Peer, Y., Lundeberg, J., Grabherr, M.G., **Street, N.R.** 2015. *Serendipitous Meta-Transcriptomics: the fungal community of Norway spruce (Picea abies)*. PLoS ONE, 10(9): e0139080.

- Funda, T., Wennström, U., Almqvist, C., Torimaru, T., **Andersson Gull, B.**, **Wang, X.-R.** 2015. *Low rates of pollen contamination in a Scots pine seed orchard in Sweden: the exception or the norm?* Scandinavian Journal of Forest Research, 30: 573-586.
- García Gil, M.R., Floran, V., Öslund, L., Mullin, T., **Andersson Gull, B.** 2015. *Genetic diversity and inbreeding in natural and managed populations of Scots pine.* Tree Genetics & Genomes, 11:28.
- Hong, Z., Fries, A., Lundqvist, S.O., **Andersson Gull, B.**, Wu, H.X. 2015. *Measuring stiffness using acoustic tool for Scots pine breeding selection.* Scandinavian Journal of Forest Research, 30:4, 363-372.
- Hu, X-G., Jin, Y., **Wang, X.-R.**, Mao, J.-F., Li, Y. 2015. *Predicting impacts of future climate change on the distribution of the widespread conifer *Platycladus orientalis*.* PLoS ONE, 10(7): e0132326.
- Khaling, E., Papazian, S., Poelman, E.H., Holopainen, J.K., **Albrechtsen, B.R.**, Blande, J.D. 2015. *Ozone affects growth and development of *Pieris brassicae* on the wild host plant *Brassica nigra*.* Environ Pollut., 199C: 119-129.
- Kucukoglu, M.** and **Nilsson, O.** 2015. *CLE peptide signaling in plants – the power of moving around.* Physiol. Plant., 155: 74-87.
- Liu, L., Ramsey, T., Zinkgraf, M., Sundell, D., **Street, N.R.**, Filkov, V., Groover, A. 2015. *A resource for characterizing genome-wide binding and putative target genes of transcription factors during secondary growth and wood formation in *Populus*.* Plant Journal, 82: 887-898.
- Mahboubi, A., **Lindén, P.**, Hedenström, M., **Moritz, T.**, Nittyllä, T. 2015. *C-13 Tracking after (CO<sub>2</sub>)-C-13 supply revealed diurnal patterns of wood formation in aspen.* Plant Physiology, 168: 478-489.
- Meng, J., Mao, J.-F., Zhao, W., Xing, F., Chen, X., Liu, H., Xing, Z., **Wang, X.-R.**, Li, Y. 2015. *Adaptive differentiation in seedling traits in a hybrid pine species complex, *Pinus densata* and its parental species, on the Tibetan Plateau.* PLoS ONE, 10(3): e0118501.
- Pan, J., Wang, B., Pei, Z.-Y., Zhao, W., Gao, J., Mao, J.-F., **Wang, X.-R.** 2015. *Optimization of the genotyping-by-sequencing strategy for population genomic analysis in conifers.* Molecular Ecology Resources, 15: 711-722.
- Petersson, S.V., **Lindén, P.**, **Moritz, T.**, Ljung, K. 2015. *Cell-type specific metabolic profiling of *Arabidopsis thaliana* protoplasts as a tool for plant systems biology.* Metabolomics, 11: 1679-1689.
- Ricroch, A., Harwood, W., Svobodová, Z., Sági, L., Hundleby, P., Badea, E.M., Rosca, I., Cruz, G., Salema Fevereiro, M.P., Marfà Riera, V., **Jansson, S.**, Morandini, P., Bojinov, B., Cetiner, S., Custers, R., Schrader, U., Jacobsen, H.J., Martin-Laffon, J., Boisron, A., Kuntz, M. 2016 (online 2015). *Challenges facing European agriculture and possible biotechnological solutions.* Critical Reviews in Biotechnology, 36:5, 875-883.
- Robinson, K.M.**, Hauzy, C., Loeuille, N., **Albrechtsen, B.R.** 2015. *Relative impacts of environmental variation and evolutionary history on the nestedness and modularity of tree–herbivore networks.* Ecology and Evolution, 5(14): 2898-2915.
- Soolanayakanahally, R.Y., Guy, R.D., **Street, N.R.**, **Robinson, K.M.**, Silim, S.N., **Albrechtsen, B.R.**, **Jansson, S.** 2015. *Comparative physiology of allopatric *Populus* species: geographic clines in photosynthesis, height growth, and carbon isotope discrimination in common gardens.* Frontiers in Plant Science, 6:528. doi: 10.3389/fpls.2015.00528.
- Stavriniidou, E., Gabrielsson, R., Gomez, E., Crispin, X., **Nilsson, O.**, Simon, D.T., Berggren, M. 2015. *Electronic plants.* Science Advances, 1: e1501136.

- Sundell, D., Mannapperuma, C., Netotea, S., Delhomme, N., Lin, Y.-C., Sjödin, A., Van der Peer, Y., **Jansson, S.**, Hvidsten, T.R., **Street, N.** 2015. *The plant genome integrative explorer resource: PlantGenIE.org*. *New Phytologist*, 208(4): 1149–1156.
- Torell, F., Bennett, K., Cereghini, S., Rännar, S., Lundstedt-Enkel, K., **Moritz, T.**, Haumaitre, C., Trygg, J. Lundstedt, T. 2015. *Multi-organ contribution to the metabolic plasma profile using hierarchical modelling*. *PLoS ONE*, 10, e0129260.
- Wang, J., **Street, N.R.**, Scofield, D.G., Ingvarsson, P.K. 2016 (online 2015). *Natural selection and recombination rate variation shape nucleotide polymorphism across the genomes of three related Populus species*. *Genetics*, 202(3): 1185-1200. doi:10.1534/genetics.115.183152.
- Wang, B., Climent, J., **Wang, X.-R.** 2015. *Horizontal gene transfer from a flowering plant to the insular pine Pinus canariensis. (Chr. Sm. Ex DC in Buch)*. *Heredity*, 114: 413–418.
- Zhang, Y.-J., Wang, W., Yang, H.-L., Li, Y., Kang, X.-Y., **Wang, X.-R.**, Yang, Z.-L. 2015. *Molecular properties and functional divergence of the dehydroascorbate reductase gene family in lower and higher plants*. *PLoS ONE*, 10(12): e0145038.

### Open access computer programs

- Delhomme, N., Mähler, N., Schifftaler, B., Sundell, D., Mannapperuma, C., Hvidsten, T.R., **Street, N.E.** 2015. Guidelines for RNA-Seq data analysis. *EpiGeneSys Protocol prot 67*.

### Scientific presentations

- Andersson Gull, B.** 2015. "Breeding and seed orchards in Sweden – how to get gain into the forest". Invited presentation at CFGA/IUFRO conference "Integrating Tree Breeding, Genomics, Silviculture, and Growth and Yield", Fredericton NB, August 17-20, 2015. <http://forestgenetics2015.ca/>

### Outreach activities

- von Bothmer, R., Fagerström T, **Jansson, S.** 2015. *Bortom GMO – Växtförädling för ett hållbart jordbruk*. Popular science book on behalf of KVA. Publisher: Förlaget Fri Tanke.
- von Bothmer, R., Fagerström, T., **Jansson, S.** 2015. *Ny genteknik kan ge stora miljövinster*. Daily newspaper: SvD Brännpunkt, April 20.
- Jansson, S.** 2015. *Det genomförs fältförsök med genetiskt förändrade hybridaspår i Laholms kommun*. – Letter to the editor in daily newspaper: Hallandsposten, April 30.
- Jansson, S.** 2015. *Curies okunniga barnbarn*. VR's online magazine Curie, May 7. <http://bloggar.tidningencurie.se/stefanjansson/curies-okunniga-barnbarn/>
- Jansson, S.** 2015. *Hur ska kommunikation om forskning premieras?* VR's online magazine Curie, May 25. <http://bloggar.tidningencurie.se/stefanjansson/hur-ska-kommunikation-om-forskning-premieras/>
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- Jansson, S.** 2015. *Fascinerande växter dag*. Intervju i local radio: SR Radio Västerbotten May 21.
- Jansson, S.** 2015. *Spirande gröna upptäckter*. Intervju in daily newspaper: Västerbottenskuiren May 24. <http://www.vk.se/plus/1455952/spirande-grona-upptackter>
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- Jansson, S.** 2015. *Växter och politik*. Presentation at Umeå University, May 27.
- Jansson, S.** 2015. *Nej, GMO och bekämpningsmedel kan inte förändra ditt DNA*. Interview in paper: Tidningen Metros Viralgranskare, May 28. <http://www.metro.se/nyheter/nej-gmo-och-bekampningsmedel-kan-inte-forandra-ditt-dna/EVHoeA!n5xJ76XDQiFcg/>
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- Jansson, S.** 2015. *Stefan Jansson – Växtprofessorn som brinner för populärvetenskap*. Interview in skrivpopulärvetenskapligt.se, August 10.  
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<https://www.gp.se/nyheter/sverige/1.2861397-lovens-roda-hostfarg-ar-solskydd>  
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**Jansson, S.** 2015. *Varför är höstlöven röda?* Radio interview: SR P4 Extra, October 12.  
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**Jansson, S.** 2015. *GMO – till nytta eller skada för mänskligheten.* Presentation at Turistföreningen Lycksele, October 20.

**Jansson, S.** 2015. *GMO ger ett mera hållbart jordbruk.* Interview in local weekly paper: Totalt Umeå, October 29. <http://www.e-pages.dk/totaltumea/143/6>

**Jansson, S.** 2015. *Vegetabilisk arsenik.* Interview in local newspaper: Västerbottenskuriren October 30. <http://www.vk.se/plus/1562447/vegetabilisk-arsenik-i-lekpark-pa-haga>

**Jansson, S.** 2015. *GMO för en hållbar framtid.* Presentation at Humanisterna Umeå, November 5. And referred to in local newspaper: <http://www.vk.se/1569997/mats-olofsson-tro-och-vetande-och-gmo>

**Jansson, S.** 2015. *Edman är oinsatt eller ärekränker.* Interview in local weekly paper: Totalt Umeå, november 7. <http://www.e-pages.dk/totaltumea/144/6>

**Jansson, S.** 2015. *GMO debatten.* Presentation at “Biotechnology days” for students in Umeå, November 7.

**Jansson, S.** 2015. *Genmodifierade växter och GMO-debatten.* Presentation at Norrmejeriers årsstämma, Skellefteå, November 8.

**Jansson, S.** 2015. *Att se ljus och äta ljus.* Presentation at The Royal Swedish Academy of Sciences (KVA) and The Swedish National Agency for Education’s (skolverket) inspiration days for teachers. Avesta, November 17.

**Jansson, S.** 2015. “Green light in the tunnel”! Swedish Board of Agriculture: a CRISPR-Cas9-mutant but not a GMO. Press release referred to nationally and internationally:

<http://sverigesradio.se/sida/artikel.aspx?programid=406&artikel=6303669>

<http://www.dn.se/ledare/signerat/carl-johan-von-seth-gor-upp-med-gmo-skracken/>

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**Jansson, S.** 2015. *Hoch hinaus*. Interview in Die Zeit, November 25.  
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### Collaboration with industry and other parts of society

Skogforsk is partially financed by the forestry industry. Through the channels of the UPSC Berzelii Centre for Forest Biotechnology, we collaborate with most of the big forestry companies in Sweden.

### Investments in research infrastructure

Funds have been used to maintain field sites for studies on natural variation in aspen (the SwAsp gardens in Ekebo and Sävar) and transgenic aspens (In Våxtorp).

### Involvement in national and international networks

Our national and international networks are very good. Our collaborators include Magnus Berggren, University of Linköping, Miguel Blazquez, IBMCP Spain, Egbert Boekema, University of Groningen, Netherlands, Jonathan Gershenzon, Max Planck Institute for Chemical Ecology, Jena, Germany, Hans Hoenicka, Thünen Institute of Forest Genetics, Grosshansdorf, Germany, Alfred Holzwarth, Max Planck Institute for Chemical Energy Conversion, Mülheim, Germany, Cristian Ibáñez, La Serena Univ. La Serena, Chile, Yao-Cheng Lin, VIB, Ghent, Belgium, Richard Lindroth University of Wisconsin, Madison, USA, Andrew Millar, Edinburgh Univ, UK, Marjaana Suorsa, University of Turku, Finland.

### Integration with different levels of education

**Pietrzykowska, M.** 2015. Doctoral thesis: *The roles of Lhcb1 and Lhcb2 in regulation of photosynthetic light harvesting*. ISBN: 978-91-7601-208-6.

**Lindén, P.** 2015. Doctoral thesis: *Monitoring primary carbon metabolism in plants using heavy isotope labelling and mass spectrometry*. Umeå: Sveriges lantbruksuniversitet. Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:58 ISBN: 978-91-576-8314-4.

**Kucukoglu, M.** 2015. Doctoral thesis: *Molecular regulation of vascular cambium identity and activity*. Umeå: Sveriges lantbruksuniversitet. Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:112 ISBN: 978-91-576-8422-6.

#### *Undergraduate teaching:*

Stefan Jansson, Ove Nilsson, Benedicte Albrechtsen and Maria Eriksson has been involved in undergraduate teaching.

## Theme 2 – Growth and interaction with the environment – current and future

The focus of Theme 2 is to understand one of the key objectives in forest research; to increase biomass yield from the existing forest estate. A cornerstone in this is to understand the responses of trees to different biotic and abiotic factors and impacts of these different factors on ecosystem stability and robustness, on tree growth and on sustainable harvestable yield. The activities of Theme 2 are divided into 4 interlinked research projects, each driven by a research leader. In addition, funding is allocated to common resources at the level of shared field sites and shared bioinformatics resources, binding the projects together into a common effort.

### Main findings in 2015

We finalized a comprehensive account of C stores and C fluxes in fertilized and non-fertilized forest. In this manuscript, two results are of particular interest. First, increased growth of fertilized trees was shown to more-or-less entirely result from altered allocation and only to a small extent result from increased resource acquisition. This implies that N-fertilization of old stands (the normal practice in Sweden) does not increase tree growth but alters allocation patterns.

The work initiated earlier on the C-N interactions in boreal forests has continued. We have developed a new technique for manipulating belowground C transport of large trees through compression of phloem tissues. This technique enables reversible inhibition of belowground C transport and its effectiveness was shown with a range of different techniques.

We have continued to develop and apply the microdialysis technique for measuring soil nitrogen fluxes in the field. We show that soil diffusive fluxes are the bottleneck for tree N nutrition.

We have assessed the effect of nitrogen fertilizer application on shoot-scale photosynthesis. The main finding being that the long-term shoot-scale net photosynthetic performance is not enhanced by higher needle N content.

Related to the above study, we have successfully parameterized the Farquhar model for predicting long-term shoot-scale photosynthetic performance at the control and high-N plots at Rosinedal.

We have also investigated the role of photosynthetic re-fixation of CO<sub>2</sub> by tree stems. The main findings are: i) stem CO<sub>2</sub> efflux exhibits strong vertical variation with the rates decreasing upward along the stem, and ii) re-fixation varies along the stem with highest rates near the top. Upscaling suggest that measuring stem respiration at breast height only, as is the common practice, will lead to strong, > 80%, overestimation of the stem CO<sub>2</sub> release from the tree trunks, which has implications on the whole tree-scale carbon cycling.

We have continued to developed methods extracting high yield and high quality RNA and DNA from field grown spruce needles, vascular cambium and roots, and from forest soils. We have generated high quality data sets from Next Generation Sequencing of soil, root- and shoot-associated fungal RNA and, with our collaborating partners, developed new RNA transcript assembler that will enable us to perform high through-put metatranscriptomic analysis of these samples. This will enable us to identify not only the active microbial community associated with these different plant tissue, but to assign expression-based biological function to the different members of this complex and changing community.

### Personnel involved in Theme 2 in 2015

Name	Gender and position	Part of full time financed by TC4F
Vaughan Hurry	M, Professor	0
Torgny Näsholm	M, Professor	0
Catherine Campbell	F, Assistant Professor	50
Zsofia Stangl	F, PhD student	100
Kathryn Robinson	F, Postdoctoral fellow	50
Benedicte Albrechtson	F, Associate professor	25
John Marshall	M, Professor	100
Ulrika Ganeteg	F, Assistant Professor	50
PanTana Tor-ngern	F, PhD student	50
Olusegun Ajodeji Oyewole	M, PhD student	100
Lasse Tarvainen	M, Postdoctoral fellow	75

### Scientific publications

*During 2015 Theme 2 has published 11 peer reviewed scientific articles financed by TC4F. Authors marked in bold represents researchers that have been financed by, or are associated to, the research program.*

Boudreault, L.-E., Bechmann, A., **Tarvainen, L.**, Klemedtsson, L., Shendryk, J., Dellwik, E. 2015. *A LiDAR method of canopy structure retrieval for wind modelling of heterogeneous forests.* Agricultural and Forest Meteorology, 201: 86-97. doi: 10.1016/j.agrformet.2014.10.014.

Brackin, R., **Näsholm, T.**, Robinson, N., Guillou, S., Vinall, K., Lakshmanan, P., Schmidt, S., **Inselsbacher, E.** 2015. *Nitrogen fluxes at the root-soil interface show a mismatch of nitrogen fertilizer supply and sugarcane root uptake capacity.* Scientific Reports, 5:15727.

- De Kauwe, M., Lin, Y.-S., Wrigh, I.J., Medlyn, B.E., Crous, K.Y., Ellsworth, D.S., Maire, V., Prentice, C., Atkin, O.K., Rogers, A., Niinemets, Ü., Serbin, S.P., Meir, P., Uddling, J., Togashi, H.F., **Tarvainen, L.**, Weerasinghe, L.K., Evans, B.J., Ishida, F.Y., Domingues T.F. 2016. (online 2015). *A test of the 'one-point method' for estimating maximum carboxylation capacity from field-measured, light-saturated photosynthesis*. *New Phytologist*, 210: 1130-1144. doi: 10.1111/nph.13815.
- He, H., Jansson, P.-E., Svensson, M., Björklund, J., **Tarvainen, L.**, Klemedtsson, L., Kasimir, Å. 2016. (online 2015). *Forests on drained agricultural peatland are potentially large sources of greenhouse gases – insights from a full rotation period simulation*. *Biogeosciences*, 13: 2305-2318, doi: 10.5194/bgd-12-19673-2015.
- Henriksson, N., Tarvainen, L., Lim, H., Tor-Ngern, P., Palmroth, S., Oren, R., Marshall, J., Näsholm, T.** 2015. *Stem compression reversibly reduces phloem transport in Pinus sylvestris trees*. *Tree Physiology*, 35: 1075-1085. doi: 10.1093/treephys/tpv078.
- Kurepin, L.V.,** Ivanov, A.G., Zaman, M., Pharis, R.P., Allakhverdiev, S.I., **Hurry, V.**, Huner, N.P.A. 2015. *Stress-related hormones and glycinebetaine interplay in protection of photosynthesis under abiotic stress conditions*. *Photosynthesis Research*, 126: 221-235.
- Lim, H., Oren, R., Palmroth, S., Tor-ngern, P., Mörling, T., Näsholm, T., Lundmark, T., Helmisaari, H.-S., Leppälammil-Kujansuu, J. Linder, S.** 2015. *Inter-annual variability of precipitation constrains the production response of boreal Pinus sylvestris to nitrogen fertilization*. *Forest Ecology and Management*, 348: 31-45.
- Lin, Y.-S., Medlyn, B., Duursma, R., Prentice, C.I., Wang, H., Baig, S., Eamus, D., Resco de Dios, V., Mitchell, P., Ellsworth, D., Op de Beeck, M., Wallin, G., Uddling, J., **Tarvainen, L.**, Linderson, M.-L., Cernusak, L., Nippert, J., Ocheltree, T., Tissue, D., Martin-StPaul, N., Rogers, A., Warren, J., De Angelis, P., Hikosaka, K., Han, Q., Onoda, Y., Gimeno, T., Barton, C., Bennie, J., Bonal, D., Bosc, A., Löw, M., Macinins-Ng, C., Rey, A., Rowland, L., Setterfield, S., Tausz-Posch, S., Zaragoza-Castells, J., Broadmeadow, M., Drake, J., Freeman, M., Ghannoum, O., Hutley, L., Kelly, J., Kikuzawa, K., Kolari, P., Koyama, K., Limousin, J.-M., Meir, P., Costa, A., Mikkelsen, T., Salinas, N., Sun, W., Wingate, L. 2015. *Optimal stomatal behaviour around the world*. *Nature Climate Change*, 5: 459-464. doi: 10.1038/NCLIMATE2550.
- Oyewole, O.,** Jämtgård, S., Gruffman, L., **Inselsbacher, E., Näsholm, T.** 2015. *Soil diffusive fluxes constitute the bottleneck to tree nitrogen nutrition in a Scots pine forest*. *Plant and Soil*, 399:109. doi: 10.1007/s11104-015-2680-5.
- Tarvainen, L.,** Rantfors, M., Wallin, G. 2015. *Seasonal and within-canopy variation in shoot-scale resource use efficiency trade-offs in a Norway spruce stand*. *Plant, Cell and Environment*, 38: 2487-2496. doi: 10.1111/pce.12565.
- Wullschleger, S.W., Breen, A.M., Iversen, C.M., Olson, M.S., **Näsholm, T., Ganeteg, U.,** Wallenstein, M.D., Weston, D.J. 2015. *Genomics in a changing Arctic: Critical questions await the molecular ecologist*. *Molecular Ecology*, 24: 2301-2309.

### Scientific presentations

During August 17-19, 2015 we organised an international workshop entitled “*Boreal forest systems in a changing climate: from physiological mechanisms to ecosystem responses*”. The workshop had 35 participants from Sweden, Finland, UK, Canada and US.

**Näsholm, T.** 2015. Presentation *Plant Nitrogen Nutrition: the simple and the complex version*. At the SPPS meeting in Stockholm August 10-12.

**Tarvainen, L.** 2015. Invited talk *Does nitrogen fertilisation enhance the photosynthetic*

*performance of boreal Pinus sylvestris?* At AiroPlant research group meeting, Department of Biological and Environmental Sciences, University of Gothenburg.

### Collaboration with industry and other parts of society

Theme 2 researchers have well developed research collaborations with industrial partners Holmen Skog AB and forest biotech companies SweTree Technologies and SweTree Nutrition.

### Involvement in national and international networks

Formally connected through common grants to a research network covering researchers in USA, Canada, UK, New Zealand and Australia, with the goal of establishing the thermal safety margins for plant respiration and photosynthesis in different biomes.

### Integration with different levels of education

**Oyewole, O.** 2015. Doctoral thesis: *Soil nitrogen fluxes and root uptake in boreal forest: key processes to plant nitrogen nutrition*. Umeå: Sveriges lantbruksuniversitet. Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:126 ISSN 1652-6880.

**Stachula, P.** 2015. Doctoral thesis: *Short and long term low temperature responses in Arabidopsis thaliana*. ISBN: 978-91-7601-319-9.

Participating researchers Vaughan Hurry, Torgny Näsholm, Catherine Campbell, Benedicte Albrechtson and Ulrika Ganeteg all participated in undergraduate teaching and postgraduate training.

## Theme 3 – Sustainable and adaptive forest management

Theme 3 is devoted to research focused on forest management using novel silvicultural methods, ensuring sustainable forest production and adaptation to climate change. Historically, management research in Sweden has mainly been concentrated to monocultures and clearfelling systems. However, an increased demand from society on more diverse forests and future climate challenges has led to an increased interest alternative silvicultural methods. Research topics of theme 3 include continuous cover forestry (CCF), regeneration, fast growing broadleaves and effects of climate change on forest growth.

### Main findings in 2015

In the CCF project, we have reported from an experiment in Halland where target diameter cutting was tested. We have also been involved in scenario analysis where different clear-cut free methods were tested in simulations with the decision support system Heureka. The field experiment on conversion to heterogeneous forests was measured and we also organized an international PhD-course (Forests for people) within the CCF project.

In the regeneration project we have investigated the effects of planting time on pine weevil damage. The early performance of planted Norway spruce and Scots pine was also studied in a field experiment in northern Sweden. The combination of planting Norway spruce and natural regeneration of birch was studied in a field experiment and effects of pre-commercial strategies was studied in a scenario analysis. Nitrogen fixation in the moss-layer and its effects

on natural regeneration of Norway spruce was studied in a chronosequence. Both biotic and abiotic factors affected mosses were important but the relative importance of various factors varied with successional stage. The results indicate that the moss-layer in boreal forests may decrease as a result of increased air-temperature due to climate change. Effects of application of charcoal after clearcutting on regeneration and soil carbon- and nitrogen storage was studied in a field experiment.

In the fast growing broadleaved project effects of clones on browsing patterns was studied in a field experiment. A nation-wide tree species experiment where poplars and hybrid aspen are compared to Scots pine and Norway spruce was established. A thinning experiment in second-generation poplars was established and measured. Field experiments on the effect of liming on early establishment and growth of poplars and fertilization in the planting spot were established. Lastly, the effect of pH and fertilization on growth of poplars and hybrid aspen was evaluated.

In the climate change project, a hybrid model was constructed in which the mechanistic model 3PG and empirical model Heureka was combined. The new model was validated against National Forest Inventory data in the county Kronoberg. Thereafter, the model was used in a scenario analysis where forest development in Kronoberg was simulated for 100 years with different climatic scenarios. In addition, new models for simulation of growth of genetically improved trees were constructed. The models will be incorporated in the simulation system Heureka in order to more realistically simulate development of genetically improved trees in a changing climate.

### Personnel involved in Theme 3 in 2015

Name	Gender and position	Part of full time financed by TC4F
Urban Nilsson	M, Professor	0
Marie-Charlotte Nilsson H.	F, Professor	0
Babs Stuvier	F, PhD student	100
Narayanan Subramanian	M, PhD student	100
Samuel Egbäck	M, PhD student	100
Lars Drössler	M, Postdoctoral fellow	70
Karin Hjelm	F, Assistant Professor	50
Henrik Böhlenius	M, Assistant Professor	50
Michael Gundale	M, Assistant Professor	20

### Scientific publications

*During 2015 Theme 3 has published 11 peer reviewed scientific articles financed by TC4F. Authors marked in bold represents researchers that have been financed by, or are associated to, the research program.*

**Böhlenius, H.** & Övergaard, R. 2015. *Growth response of hybrid poplars to different types and levels of vegetation control.* Scandinavian Journal of Forest Research, 30(6): 516-525. doi: 10.1080/02827581.2015.1034768.

**Böhlenius, H.** & Övergaard, R. 2015. *Exploration of optimal agricultural practices and seedling types for establishing poplar plantations.* Forests, 6(8): 2785-2798. doi:10.3390/f6082785.

- Drössler, L.**, Övergaard, R., Ekö, P.M., Gemmel, P., **Böhlenius, H.** 2015. *Early development of pure and mixed tree species plantations in Snogeholm, southern Sweden*. Scandinavian Journal of Forest Research, 30(4): 304-316, doi: 10.1080/02827581.2015.1005127.
- Drössler, L.**, Ekö, P.M., Balster, R. 2015. *Short-term development of a multi-layered forest stand after target diameter harvest in southern Sweden*. Canadian Journal of Forest Research, 45(9): 1198-1205, doi: 10.1139/cjfr-2014-0471.
- Gundale, M.J.**, **Nilsson, M.-C.**, Pluchon, N., Wardle, D.A. 2015. *The effect of biochar management on soil and plant community properties in a boreal forest*. Global Change Biology Bioenergy, doi: 10.1111/gcbb.12274.
- Johansson, K.**, Hajek, J., Sjölin, O., Normark, E. 2015. *Early performance of Pinus sylvestris and Picea abies – a comparison between seedling size, species and geographic location of the planting site*. Scandinavian Journal of Forest Research, 30(5): 388-400. doi:10.1080/02827581.2014.987808.
- Jonsson, M., Kardol, P., **Gundale, M.**, Bansal, S., **Nilsson, M.-C.**, Metcalfe, D., Wardle, D.A. 2015. *Direct and indirect drivers of moss community structure, function and associated microfauna across a successional gradient*. Ecosystems, 18: 154-169.
- Pluchon, N., Casetou, S.C., Kardol, P., **Gundale, M.J.**, **Nilsson, M.-C.**, Wardle, D.A. 2015. *Influence of species identity and charring conditions on fire-derived charcoal traits*. Canadian Journal of Forest Research, 45: 1669-1675.
- Puettman, K.J., Wilson, S., Baker, S., Donoso, P., **Drössler, L.**, Amente, G., Harvey, B.D., Knoke, T., Lu Y., Noncentini, S., Putz, F.E., Yoshida, T., Bauhus, J. 2015. *Silvicultural alternatives to conventional even-aged forest management - what limits global adoption?* Forest Ecosystems, 2: 8, doi: 10.1186/s40663-015-0031-x.
- Subramanian, N.**, Karlsson, P.-E., Bergh, J., **Nilsson, U.** 2015. *Impact of ozone on sequestration of carbon by Swedish forests under a changing climate: A modeling study*. Forest Science, 61, 445-457.
- Stuiver, B.M., Gundal, M.J., Wardle, D.A., **Nilsson, M.-C.** 2015. *Nitrogen fixation rates associated with the feather mosses Pleurozium schreberi and Hylocomium splendens during forest stand development following clear-cutting*. Forest Ecology and Management, 347: 130-139.

### Scientific presentations

- Nilsson, U.**, Felton, A., Lämås, T., Lundmark, T., Nordin, A., Ranius, T., Roberge J.-M., Sonesson, J. 2015. *Conservation biologists need to take a more active interest in interest rates: Linking economic drivers to habitat availability in production forests*. 17th IBFRA Conference, Towards a New Era of Forest Science in the Boreal Region. Rovaniemi, Finland, May 24-29.

We organized a conference for Nordic growth and yield researchers during June 16-18. The conference included a day and a half of indoor presentations and a day and a half of field excursions.

### Outreach activities

- Hjelm, K.** 2015. Excursion. *Intensive silviculture – Regeneration issues*. Tönnersjöheden, April 21.
- Hjelm, K.** 2015. Excursion. *Establishment of poplar and hybrid aspen*. National Poplar Commission, Härkeberga. September 3.

- Nilsson, U.** 2015. *Continuous cover forestry – growth and development*. KSLA seminar. April 28.
- Nilsson, U.** 2015. Excursion. *Silviculture*. Siljansfors, Bergvik and Billerud Korsnäs. April 17.
- Nilsson, U.** 2015. Excursion. *Silviculture in Scots pine*. Lönsboda, IKEA. May 7.
- Nilsson, U.** 2015. Excursion Skogforsk board, Asa, June 2.
- Nilsson, U.** 2015. Excursion. *Thinning of Scots pine and lodgepole pine*. Västerbotten, June 23.
- Nilsson, U.** 2015. *Non-native species to spread the risk and increase the forest adaptation potential*. ENERWOOD seminar, August 27.
- Nilsson, U.** 2015. Excursion. *Silviculture in Scots pine*. Sävsjöström och Linnebjörke, October 6.
- Nilsson, U.** 2015. Excursion. *Pre commercial thinning*. Småland, Södra. October 29.

### Collaboration with industry and other parts of society

Theme 3 has been involved in numerous presentations and excursions with participants from the forest sector. Forest companies have been involved in several of our field experiments, either directly as partners or indirectly as landowners.

### Involvement in national and international networks

We are participating in an international network with the aim to construct new models for estimating site productivity. This network involves researchers from New Zealand, Chile, Sweden and USA. We are also active in the Nordic network for growth and yield research. Within this network, we are currently involved in projects on continuous cover forestry and mortality models for old forest stands.

### Integration with different levels of education

- Holmström, E.** 2015. Doctoral thesis: *Regeneration and early management of birch and Norway spruce mixtures in southern Sweden*. Alnarp: Sveriges lantbruksuniversitet. Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:122. ISBN: 978-91-576-8442-4.
- Stuiver, B.** 2015. Doctoral thesis: *Stand development effects on N<sub>2</sub>-fixation and seedling performance in northern boreal forests*. Uppsala: Sveriges lantbruksuniversitet. Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:108. ISBN: 978-91-576-8414-1

#### PhD-course:

During August 2015 we organized a two-week summer course “*Forest for people*” for international PhD-students. The course included a travel in southern Sweden with excursions to various experiments.

## Theme 4 – Other renewable plant resources, non-food crops

The overall objective of theme 4 is to improve important plant properties using both conventional and modern plant breeding methods, such as biotechnological and omics-approaches and to develop sustainable new biobased products for the biobased society. Our research activities are often incorporated with other large research projects. The research activities are mainly focused on the improvement of oil and starch qualities and quantities, production of biobased materials, analysis of starch and protein properties in relation to the qualities of biobased products and materials.



## Main findings in 2015

In 2015 we demonstrated that wheat proteins have the ability to absorb large amounts of water. The proteins were foamed to obtain a material with high water absorbency and they can take up water as much as superabsorbent polymers (SAP), which are often used in hygiene products and disposable diapers and sanitary napkins. Our finding indicates that plant proteins can be used as new super-absorbents for diapers or for other uses.

We have produced composites of wheat gluten (WG) protein and a novel genetically modified potato starch (MPS) with attractive mechanical and gas barrier properties. MPS revealed an altered chain length distribution of amylopectin and slightly increased amylose content compared to wild type potato starch. The composites made from different ratios of WG and MPS showed MPS had semicrystalline structure, of which one WG-MPS composite showed excellent gas barrier properties that can be further explored in multilayer film packaging applications.

We have also evaluated novel ways to modify gluten protein macromolecular structures by separation methods and additives.

We have found specific characters of potato proteins when plasticized and pressed and these proteins would be of interest for further evaluation for production of biobased materials as well as perhaps other unknown applications.

We have developed a rice line called SUSIBA2 by expressing a barley transcription factor. This new line has the capacity to redirect the internal allocation of carbon compounds produced by photosynthesis from the roots to the aboveground tissues, resulting in rice plants with suppressed methane emissions over 90% and increased yield, indicating its high potential in contribution to the food security in an environmentally friendly manner.

We have found that transient inhibition of KASII expression in leaves of *N. benthamiana* could lead to a shift of carbon flux from C18 to C16 fatty acid, and increased wax ester production. This demonstrates that transient inhibition of KASII in vegetative tissues of higher plants enables metabolic studies towards industrial production of lipids such as wax esters with specific quality and composition.

We have developed crambe transgenic lines with ultra-high oleic oil through RNAi-downregulation of two important genes involved in the fatty acid biosynthesis. The high oleic trait has been stable for a number of generations under greenhouse conditions. This achievement has added an important value to crambe as an industrial crop as oleic oil has a number of important industrial applications.

We have found that high-amylose potato starches have changed granule morphology and composition with increased chain length of amylopectin. These changes have enhanced film-forming behavior and improved barrier and tensile properties in starch films. Such films exhibit significantly higher stress and strain at break compared with films of wild-type starch. These properties make the modified starches an interesting candidate for replacement of non-renewable oxygen and grease barrier polymers used today.

## Personnel involved in Theme 4 in 2015

Name	Gender and position	Part of full time financed by TC4F
Li-Hua Zhu	F, Professor	0
Eva Johansson	F, Professor	0
Sten Stymne	M, Professor	0
Anders Carlsson	M, Professor	0
Roger Andersson	M, Professor	0
Ramune Kuktaite	F, Researcher	50
Sven-Erik Svensson	M, Researcher	35
Mariette Andersson	F, Researcher	0
William (Bill) Newson	M, Postdoc	100
Faraz Muneer	M, PhD student	0
Elaine Ceresino	F, Researcher	0
Ida Lager	F, Researcher	30
Mirela Beganovic	F, Technician	10
Per Hofvander	M, Researcher	30
Åsa Grimberg	F, Researcher	30
Annelie Ahlman	F, Technician	40
Xueyuan Li	M, Research assistant	50
Simon Jeppsson	M, PhD student	100 (3 months)
Faiza Rasheed	F, Postdoc	100
Joel Marklund	M, PhD student	100 (3 months)
Emelie Ivarson	F, PhD student	0
Carolin Menzel	F, PhD student	67 %
Gunnel Fransson	F, Technician	17 %
Maria Luisa Prieto-Linde	F, Technician	0
Chuanxin Sun	M, Researcher	36 (12 months)
Selcuk Aslan	M, PhD student	100 (3 months)
Folke Sitbon	M, Researcher	0

## Scientific publications

During 2015 Theme 4 has published 19 peer reviewed scientific articles financed by TC4F. Authors marked in bold represents researchers that have been financed by, or are associated to, the research program.

- Rasheed, F.**, Hedenqvist, M.S., **Kuktaite, R.**, Plivelic, T.S., Gällstedt, M., **Johansson, E.** 2015. *Mild gluten separation – A non-destructive approach to fine tune structure and mechanical behaviour of wheat gluten films.* Ind Crops Prod, 73: 90-98.
- Rasheed, F.**, **Newson, W.R.**, Plivelic, T.S., **Kuktaite, R.**, Hedenqvist, M.S., Gällstedt, M., **Johansson, E.** 2015. *Macromolecular changes and nano-structural arrangements in gliadin and glutenin films upon chemical modification.* Int J Biol Macromol, 79: 151-159.
- Johansson, E.**, Prade, T., Angelidaki, I., **Svensson, S.-E.**, **Newson, W.R.**, Gunnarsson, I.B., Persson Hovmalm, H. 2015. *Economically viable components from Jerusalem artichoke (*Helianthus tuberosus*) in a biorefinery concept.* Int J Mol Sci, 16: 8997-9016.
- Newson, W.R.**, **Rasheed, F.**, **Kuktaite, R.**, Hedenqvist, M.S., Gällstedt, M., Plivelic, T.S., **Johansson, E.** 2015. *Commercial potato protein concentrate as a novel source for thermoformed bio-based plastic films with unusual polymerization and tensile properties.* RSC Adv, 5: 32217-32226.

- Muneer, F., Andersson, M., Koch, K., Menzel, C., Hedenqvist, M.S. Gällstedt, M., Plivelic, T.S., Kuktaite, R.** 2015. *Nanostructural morphology of plasticised wheat gluten and modified potato starch composites: relationships to mechanical and barrier properties.* Biomacromol, 16: 695-705.
- Li, X., Mei, D., Liu, Q., Fan, J., Singh, S., Green, A., Zhou, X.-R., Zhu, L.-H.** 2016 (online 2015). *Down-regulation of crambe fatty acid desaturase and elongase in Arabidopsis and crambe resulted in significantly increased oleic acid content in seed oil.* Plant Biotechnology Journal, 14(1): 323-331. doi: 10.1111/pbi.12386.
- Guan, R., Li, X., Hofvander, P., Zhou, X.-R., Wang, D., Stymne, S., Zhu, L.-H.** 2015. *RNAi targeting putative genes in phosphatidylcholine turnover results in significant change in fatty acid composition in Crambe abyssinica seed oil.* Lipids, 50: 407-16.
- Lager, I., Glab, B., Eriksson, L., Chen, G., Banas, A., Stymne, S.** 2015. *Novel reactions in acyl editing of phosphatidylcholine by lysophosphatidylcholine transacylase (LPCT) and acyl-CoA:glycerophosphocholine acyltransferase (GPCAT) activities in microsomal preparations of plant tissues.* Planta, 241: 347-58
- Nicolia, A., Proux-Wéra, E., Åhman, I., Onkokesung, N., Andersson, M., Andreasson, E., Zhu, L.-H.** 2015. *Targeted gene mutation in tetraploid potato through transient TALEN expression in protoplasts.* J Biotechnol, 204: 17-24.
- Grimberg, Å., Carlsson, A.S., Marttila, S., Bhalerao, R., Hofvander, P.** 2015. *Transcriptional transitions in Nicotiana benthamiana leaves upon induction of oil synthesis by WRINKLED1 homologs from diverse species and tissues.* BMC Plant Biol. 15:192. doi: 10.1186/s12870-015-0579-1.
- Aslan, S., Hofvander, P., Dutta, P., Sun, C., Sitbon, F.** 2015. *Increased production of wax esters in transgenic tobacco plants by expression of a fatty acid reductase:wax synthase gene fusion.* Transgenic Res. 24(6): 945-953.
- Aslan, S., Hofvander, P., Dutta, P., Sitbon, F., Sun, C.** 2015. *Transient silencing of the KASII genes is feasible in Nicotiana benthamiana for metabolic engineering of wax ester composition.* Sci Rep, 5:11213. doi: 10.1038/srep11213.
- Su, J., Hu, C., Yan, X., Jin, Y., Chen, Z., Guan, Q., Wang, Y., Zhong, D., Jansson, C., Wang, F., Schnürer, A., Sun, C.** 2015. *Expression of barley SUSIBA2 transcription factor yields high-starch low-methane rice.* Nature, 523, 602-606 (doi:10.1038/nature14673) as a featured paper.
- Källman, A., Bertoft, R., Koch, K., Sun, C., Åman, P., Andersson, R.** 2015. *Starch structure in developing barley endosperm.* International Journal of Biological Macromolecules, 81, 730-735.
- Jin, Y., Su, J., Liu, C., Sun, C.** 2015. *New energy crops for biofuel production.* In Handbook of clean energy systems, ISBN: 978-1-118-38858-7, Yan J. eds (John Wiley & Sons, Ltd.), 49-61.
- Källman, A., Bertoft, E., Koch, K., Sun, C., Åman, P. and Andersson, R.** 2015. *Starch structure in developing barley endosperm.* Int. J. Biol. Macromol, 81: 730-735.
- Källman, A., Vamadevan, V., Bertoft, E., Koch, K., Seetharamana, K., Åman, P., Andersson, R.** 2015. *Thermal properties of barley starch and its relation to starch characteristics.* Int. J. Biol. Macromol, 81: 692-700.
- Menzel, C., Andersson, M., Andersson, R., Vázquez-Gutiérrez, J. L., Daniel, G., Langton, M., Gällstedt, M., Koch, K.** 2015. *Improved material properties of solution-cast starch films: Effect of varying amylopectin structure and amylose content of starch from genetically modified potatoes.* Carbohydr. Polym, 130: 388-397.

**Muneer, F., Andersson, M., Koch, K., Menzel, C., Hedenqvist, M.S., Gällstedt, M., Plivelic, T.S., Kuktaite, R.** 2015. *Nanostructural morphology of plasticized wheat gluten and modified potato starch composites: Relationship to mechanical and barrier properties.* *Biomacromolecules*, 16(3): 695-705.

### Scientific presentations

**Kuktaite, R. & Newson, B.** 2015. Presentation: *Protein based materials.* Packbridge research forum. Lund, May.

**Kuktaite, R.** 2015. Presentation: *Bio-resources for innovative and sustainable non-food uses – Realising bio-economy in the Baltic Sea region.* Warsaw, Poland. March.

**Kuktaite, R.** 2015. Presentation: *How can we tune the plant protein structure and function in bio-based materials using SAXS and WAXS.* MAX IV workshop, Lund, September.

**Kuktaite, R.** 2015. Presentation: *Protein based bioplastics.* Maputo, Mozambique, October.  
**Jasieniecka-Gazarkiewicz, K., Lager, I., Carlsson, A.S., Stymne, S., Banas, A.** 2015. Poster presentation: *Phenotypic effect of overexpression of genes encoding acyl-CoA:lysophosphatidylethanolamine acyltransferase (LPEAT) in A. thaliana.* 7<sup>th</sup> European Symposium on Plant Lipids. Rothamstedt, UK, July 5-8.

**Lager, I., Glab, B., Patton-Vogt, J., Banas, A., Stymne, S.** 2015. Poster presentation: *Biochemical properties of Yeast Glycerophosphocholine Acyltransferase (GPCAT).* 7<sup>th</sup> European Symposium on Plant Lipids. Rothamstedt, UK. July 5-8.

**Ivarson, E., Ahlman, A., Leiva, N., Bülow, L., Zhu, L-H.** 2015. Poster presentation: *Increasing oil content in Lepidium campestre by genetic engineering.* 7<sup>th</sup> European Symposium on Plant Lipids. Rothamstedt, UK. July 5-8.

**Grimberg, Å., Carlsson, A., Hofvander, P.** 2015. Poster presentation: *Transcriptional transitions in Nicotiana benthamiana leaves upon induction of oil synthesis by WRINKLED1 homologs from diverse species and tissues.* 7<sup>th</sup> European Symposium on Plant Lipids. Rothamstedt, UK. July 5-8.

**Guan, R., Almeida, B., Li, X., Kushwaha, S., Hofvander, P., Stymne, S., Zhu, L-H.** 2015. Presentation: *Comparative transcriptome analysis of Crambe abyssinica during the seed development emphasized on lipid metabolism and erucic acid accumulation.* 13th Euro Fed Lipid Congress. Florence, Italy. September 27-30.

**Sun, C.** Presentation on *SUSIBA2 rice* for the European Rice Convention, Dubrovnik. 2015.

**Sun, C.** 2015. Presentation: *Development of GMO in China – with special focus on rice.* For the meeting “Modern Gene Technology” in Uppsala organized by Bioconsult AB, Sweden.

**Andersson, R.** 2015. Presentation: *Recent findings about the link between starch molecular structure and its physical properties.* The 32nd Nordic Cereal Congress, Espoo, Finland.

### Outreach activities

**Muneer, F., Percheron, T., Ceresino, E., Kuktaite, R.** 2015. Poster presentation. *Potato based materials*, at Borgeby fältdagar, Borgeby, June.

**Newson, B.** Oral presentation. *Plastic material from industrial oil seed residual*, at Partnerskap Alnarp, January.

**Kuktaite, R.** Oral presentation. *Projects at the Plant Product Quality Group*, at Partnerskap Alnarp, January.

**Kuktaite, R.** Oral presentation. *Protein and protein-starch materials*, at meeting with Lyckeby Starch AB, Alnarp, November.

**Stymne, S.** Oral presentation. *Breeding for life. How perennial crops keep the soil in place, increase fertility and sequester carbon in the soil*, at S.O.S. – Save Our Soils Conference arranged by KSLA, Malmö, May 20.

**Stymne, S.** Interview for Swedish Radio P4 Malmöhus: “Fältkrassing förädlas för olja”, August.

- Stymne, S.** Interview for article in Lantmannen Nr. 8, 2015. "Genombrott för ny oljeväxt".
- Zhu, L-H.** Oral presentation. *Kan genmodifierade växter bli framtidens råvarubas för industriella smörjmedel?* Underhåll & Driftsäkerhet, 2015.
- Sun, C.** 2015. Article "Low-Methane Rice for the Planet". Pan European Networks: Science & Technology 17: 266-267.
- Sun, C.** 2015. Presentations to comment on feasibilities and potentials of plant biotechnology and genetic engineering in rice breeding for food security and climate change on German Public Radio, *Science Magazine*, Los Angeles Times, MIT Technology Review, New Scientist, Scientific American, the Economist, Newsweek Magazine, Financial Times weekend magazine, Swedish Radio, Swedish TV and many daily Newspapers such as UNT, DN, China Daily and Dutch Daily.

### Collaboration with industry and other parts of society

Theme 4 has successful collaboration with Bona AB, Malmö regarding plant oils for coating and with Lantmännen for barley carbon allocation research. We have also received three new grants from Partnerskap Alnarp for collaboration with Syngenta and Lyckeby as well as a Vinnova grant for collaboration with SCA and Lantmännen.

### Involvement in national and international networks

P2F, Food kic, wheat initiative, Plant Breeding platform, SLU. Mistra Biotech, PlantLink.

### Integration with different levels of education

- Aslan, S.** 2015. Doctoral thesis: *Metabolic engineering for production of complex lipids in tobacco (Nicotiana benthamiana) leaves and rice (Oryza sativa) endosperm*. Uppsala: Sveriges lantbruksuniversitet. Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:8 ISBN 978- 91-576-8214-7.
- Newson, W.** 2015. Doctoral thesis: *Bio-based materials from crambe and carinata industrial oilseed meals*. Alnarp: Sveriges lantbruksuniversitet. Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:127 ISBN: 978-91-576-8352-9.
- Rasheed, F.** 2015. Doctoral thesis: *Tailoring the structure-function relationship in wheat gluten*. Alnarp: Sveriges lantbruksuniversitet. Acta Universitatis agriculturae Sueciae, 1652-6880; 2015:13 ISBN: 978-91-576-8224-6.

#### On-going PhD students:

- Emelie Ivarson
- Faraz Muneer

#### New PhD-students coming in to the research environment:

- Joel Markgren
- Evelyn Ceresino
- Simon Jeppson
- Per Snell
- Magnus Carlsson

#### Master students:

- One French Masters student doing internship
- Several masters from SLU

#### Teaching:

- Master course in Mozambique

- Ph.D. course, September to December 2015. "*Plant Lipid Biochemistry*" 4.5 ECTS.

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

- Vinnova grant Problöja 5 MSEK for 4 years
- Formas grant 3 MSEK for three years
- Pro2Food project EU Horizon 2020 project.
- SSF grant, 32MSEK. Oil crops for the Future for 5 years
- SSF grant, 4.2 MSEK, Recombinant protein production in plants for 5 years
- Formas grant, 5.744 MSEK. Decryption of dialogues between SUSIBA2 rice and methanogens benefits the global environment.



Trees and Crops for the Future – TC4F – is a strategic research area (SRA) funded by the Swedish government. It is a joint research effort between The Swedish University of agricultural Sciences (SLU), Umeå University (UmU) and The Forestry Research Institute of Sweden (Skogforsk).

