Final report

for the CORE Organic Plus funded project

"Crop diversification and weeds
Acronym: *PRODIVA*"

Period covered: 1st March 2015 – 30th June 2018

Index

1. Consortium

Project acronym:	PRODIVA	**Project ID:**	No. 1381
Project title:	Crop diversification and weeds		
Project website:	http://projects.au.dk/coreorganicplus/research-projects/prodiva/		
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Start of project:	1 March 2015	End date of project:	28 February 2018
Duration in months:	39	New end date in case of a project extension:	31 May 2018

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1) University, Public research centre, Private research centre, Company, Other
2) PC = Project coordinator, WPL = Work package leader, WPCL = Work package co-leader, P = Participant

2. Summary

2.1 Post-term project summary suitable for web publication

Diversification of crop sequences (WP 1): Perennial weed species can be managed when cover crops / green manure crops are included in the crop sequence but interventions must be species dependent, e.g. *Elytrigia repens* can be promoted by green manures because they prevent post-harvest cultivations. *Cirsium arvense* and *Sonchus arvensis* are two perennials that can be controlled by full-season grass-clover subjected to regular mowing for green manuring purposes and this measure has immediate application.

Cover crops for diversification (WP 1):

- Fast growing cover crops producing copious biomasses are generally useful for the suppression of weeds but need to be abandoned when severe infestations of *Elytrigia repens* require post-harvest cultivations for effective control. Growers should pay attention to the growth characteristics of cover crops when deciding on species.
- Clover species like alsike clover, red clover and white clover are suitable cover crops for weed suppression including other attributes beneficial to crop production under Northern conditions. Not only cover crop species but also their varieties are of interest. This knowledge has immediate application and legumes will have fertility building benefits as well. Vigorous cover crop growth after harvest enhances both the competition against weeds and nitrogen accumulation in the soil.
- Some cover crop species (e.g. *Melilotus alba*) can remain troublesome volunteer weeds, particularly if reduced tillage is applied. An important constrain for consideration when planning the inclusion of cover crop in the cropping system.

Crop species mixtures (WP 2): Sole pea is a weak competitor in comparison with spring barley. Intercropping the two species has not demonstrated a consistent and greater suppressive ability against weeds than sole spring barley. Thus, clear recommendations cannot be made on the basis of the work in PRODIVA.

Mixtures of spring barley or oat varieties (WP 3): Variety mixtures did not deviate much in their competitive abilities in comparison with the varieties grown solely. The most promising blends were often those containing a competitive variety that was also highly competitive when grown solely. Use of variety mixtures in practise should be reasoned in considerations regarding yield preservation and the alleviation of leaf diseases.

Weed survey and information retrieval (WP 4): Crop diversity management on 71 farms involved region specific practices. Surveys of weed species and abundances of 207 fields with organic spring cereals indicated region specific weed communities. Only few effects of the crop diversification measures applied on the farms could be related to weed species and densities.

Stakeholder involvement (WP 5): PRODIVA provides an applied overview of the most problematic weed species in the participating regions. This information to farmers and the public is made in all PRODIVA national languages. Success stories of farmers using crop diversification measures revealed crop compositions in rotations as the most important tool for weed management.

2.2 Short process update of the whole project

- Overall, the project ran as planned.
- WP1: no deviations from original planning.
- WP2: no deviations from original planning.
- WP3: no deviations from original planning.
- WP4: Data from all surveyed fields (weeds and management practises) is analysed, no deviations from the original planning.

- WP5: Expert database was established, results communicated in seven languages. Farmers networks were established in five countries and success stories were selected. No deviations from the original planning.

3. Main results, discussion, conclusions and fulfilment of objectives

WP1	Weed dynamics in crop rotations with cover crops
WP leader: Jukka Salonen (Luke) Responsible partners: Livija Zarina (AREI), Bo Melander (AU)	

Overall summary of main results, discussion and conclusions of WP1

Utilization of crop diversification for weed management in North European organic arable cropping systems was studied in the project. A wide variety of cover crop species (CCs) in crop rotations has turned out a feasible means to obtain diversification in organic cropping systems. The challenge in organic cropping is to provide strong weed suppression without severely compromising weed species diversity and crop yields. The potential of cover crops to assist the main crop in weed suppression was studied in Denmark, Finland and Latvia. Moreover, the importance of crop sequencing in weed management was demonstrated with outcomes from long-term field experiments.

Relevant data from previous crop rotation experiments (DK, LV) were extracted and analyzed to understand the effect of crop sequencing on weed growth. Perennial weed species can be managed when cover crops / green manure crops are included in the crop sequence but interventions must be species dependent. For instance, *Cirsium arvense* can be controlled by full-season grass-clover subjected to regular mowing for green manuring purposes. In contrast, grass-clover, legumes and cereal-legume mixtures rather contributed proliferations of *Elytrigia repens* in Danish experiments. Fast growing cover crops producing copious biomasses are generally useful for the suppression of weeds but need to be abandoned when severe infestations of *E. repens* require post-harvest cultivations for effective control.

Soil samples were taken from an ongoing long-term crop rotation/cover crop experiment at Foulum Research Centre (DK). The data reflected the accumulation of weed species in the seed bank that has developed during almost 20 years. It was shown that when grass-clover was grown as a green manure for 25 % of the time or more, the weed seed bank was more than halved as compared to the rotation without grass-clover.

As shown in Finnish field experiments during 2015-2017, cover crops (clover species and grasses) undersown with spring cereals in early spring, were too slow to effectively hamper the emergence and early growth of annual weed species. However, later in the growing season, and particularly after cereal harvest, they interfered with remaining weeds. Clover species have both a vigorous late-season growth and nitrogen supply for subsequent crops. Therefore, cover crop termination by tillage should be delayed until late autumn or next spring to benefit from this late weed suppression. Not only plant species but also their varieties are of interest because of their differences in seed production and overwintering; Italian ryegrass is an example of a plant with plasticity in different growing conditions.

Promising weed control was achieved by sowing the cover crop mixtures in winter wheat at the early tillering stage of crop in the spring. With an optimal CC mixture, seed rate and sowing time, no significant yield losses were detected in a sufficiently tall and dense crop. Weed management with CCs in reduced tillage systems was not successful and perennial species (e.g. *Cirsium arvense, Sonchus arvensis*) became more abundant than in the plots with conventional ploughing at the depth of 25 cm.

In all, weed management in organic systems can be enhanced by the following five basic rules:
- Design crop sequences with diverse crop types, cover crops and their management practices
- Include in rotations at least 20% N-fixating perennial crops suitable for mowing

- Leave room for mechanical control of *Elytrigia repens* whenever necessary
- Keep row crops clean from weeds
- Make good use of crop competitiveness

Stakeholder interactions included discussions about crop sequencing and cover crop use with organic farmers (WP4), scientific communication in journals and international/national conferences and visitors in field experiments. Project web-site, leaflet and news facilitated the dissemination. The literature review on weed management and cover crops was compiled (in Finnish and English) by searching literature databases and by making requests to relevant expertise and researchers.

Sustainable crop production calls for integrated weed management approaches. Insight for the most suitable cover crop species for North European conditions were compiled based on the experiences from field experiments with a special emphasis on weed suppressing ability. Weed suppression by cover crops should been seen as long-term strategy to be applied whenever feasible in diversified crop sequences.

Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:
Data from a long-termed crop rotation experiment conducted at two sites in Denmark were analysed for the growth of perennial weeds in relation to crop sequences, management schemes and cover crops (Melander et al. (2016). Agriculture, Ecosystems and Environment 220, 184-192). Severe outbreaks of perennial weed problems happened later at the site having the highest soil fertility, whereas the other site showed dynamic growth of *Cirsium arvense* and *Elytrigia repens* from early on. Grain legumes tended to promote the growth of *C. arvense*, while manuring was neutral to *C. arvense* but beneficial to *E. repens*. Cover crops assisted the growth of *E. repens* since prolonged mechanical interventions were not possible. *Cirsium arvense* and later *Sonchus arvensis* were suppressed by full-season grass-clover subjected to regular mowing for green manuring purposes whilst grass-clover actually promoted the growth of *Elytrigia repens*. The outcome of the analyses is in line with previous Danish analyses on *Elytrigia repens* dynamics in organic cropping systems on coarse sand (Rasmussen et al. (2014). European Journal of Agronomy 58, 18-27). Hence, management schemes need to be species specific. Soil samples for seed bank assessments from the site with high soil fertility showed that grass-clover in the rotation for more than 25 % of the time had halved the seed bank as compared to a rotation with cash crops only.

Among the studied legume species in Finland, low-growing *Trifolium pratense* L. and *T. repens* L. were more suitable CCs than the tall species *T. incarnatum* L. and *T. resupinatum* L. var. majus Boss. Italian ryegrass (*Lolium multiflorum* Lam.) fitted well in mixtures with clovers but failed when sown alone in winter wheat. White sweet clover (*Melilotus alba* Med.) was highly aggressive both as a CC in 2016 and as a volunteer weed in 2017, particularly in reduced tillage.

Successful germination and early growth of CCs is more important than the seed rate of CCs. Most of the treatments in Finnish field experiments were sown at the depth of 1-2 cm which turned out to be more reliable than broadcasting the CC seeds in the crop stand later in the growing season. Some treatments included a supplementary sowing of CCs after cereal harvest. Neither this method was successful in dry autumn 2016. Sowing the cover crops post-harvest was also less successful in Latvia in 2017 but this time is was due to rain delaying harvest and thus subsequent establishment and growth of the CC.

Sowing of CCs in winter cereals in early spring has not been a common practice, at least not in Finland. Promising results were achieved in Luke's field experiments in 2016; CCs were sown with the sowing machine equipped with disc coulters, which placed the CC seeds at the depth of 1-2 cm. The establishment of winter wheat was well ahead and not severely hampered by CCs during the growing season. CC treatments reduced the biomass production of *Tripleurospermum inodorum* (MATIN) which was the most abundant weed species in the field (Fig 1).

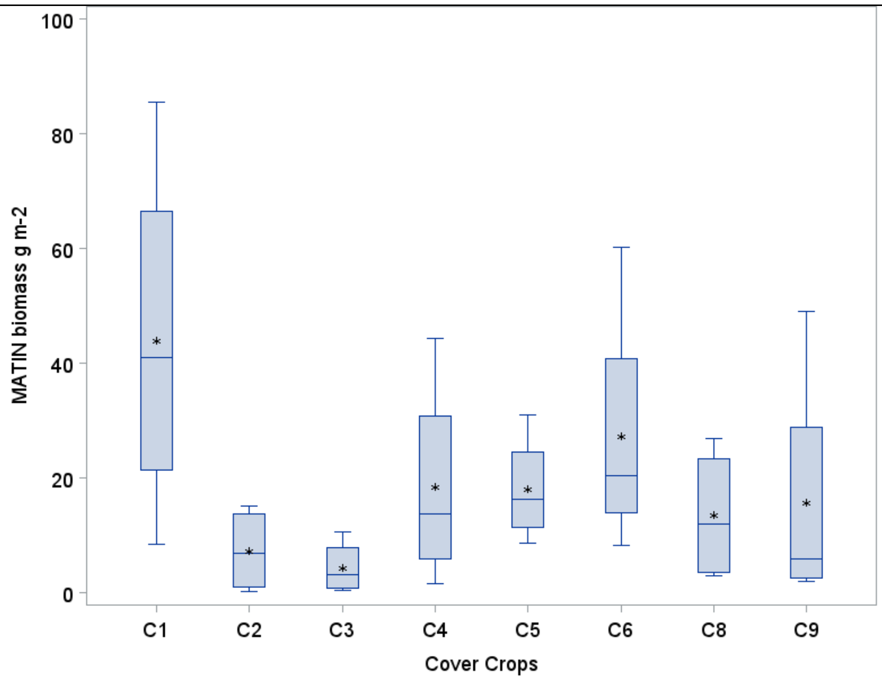

Fig. 1. *Effect of cover crop mixtures (C2-C9) on weed biomass (MATIN) in winter wheat in 2016. The best weed suppression was achieved with clover mixtures (C2 and C3). C1 is a control plot without CCs.*

Managing CCs and weeds remain questionable in reduced tillage systems, which favor the proliferation of perennial weeds in particular. Annual weed species that emerged early in the spring and grew fast and tall were not effectively suppressed with CCs. In addition to natural weed species in the field, oilseed turnip rape was used as a "model weed" in spring barley in 2015. CCs were incapable to hamper the emergence and growth of model weed. CC competition against weeds increased towards and after harvest time and therefore more profound studies on weed seed/rhizome suppression are needed. Weed diversity, i.e. the number of weed species, increased during the 3-year period in Finnish field experiments. No difference between the plots with and without CCs was observed in this respect.

In Latvia, weed density in grassland, one year after barley with undersown clover-timothy, was significantly lower than without undersowing. Clover species suppressed weeds better than ryegrass species (Fig. 2). The benefits of diversifying crop sequences with competitive crops and cover crops became evident in long-term experiments. Even *E. repens* was suppressed by including undersown red clover, clover mulch and winter rye in the crop rotation.

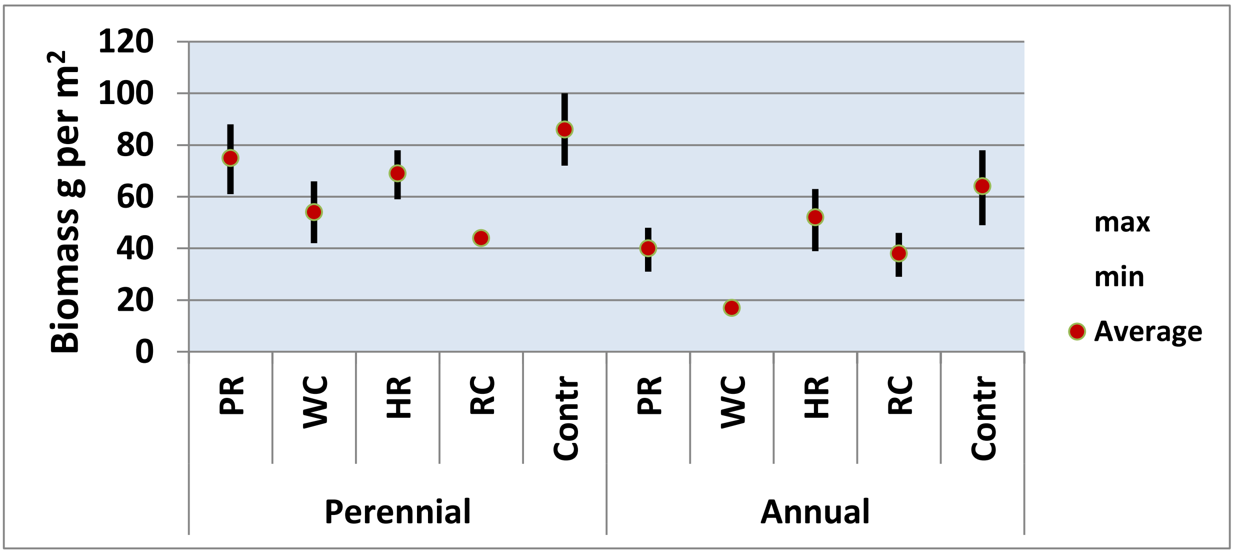

Fig. 2. Weed biomass in spring barley with undersown cover crops. PR = Perennial ryegrass, WC = White clover, HR = Hybrid ryegrass, RC = Red clover, Contr = No cover crop.

B- fulfilment of objectives:
The relative competitiveness of cover crops and their role in diverse crop sequences for weed management were clarified. The literature review on weed management with cover crops was published. A set of relevant results for scientific articles will be utilized even after the project.

Field experiments demonstrated the potential of cover crops to provide weed suppression without severely compromising crop yields. The analyses made on crop sequence and the weed control methods associated with the specific crops grown clearly revealed that noxious perennial weeds can be suppressed by crop choice and cover crop management including the control interventions that are possible to employ. Pertinent choice of cover crops and their mixtures enhances biodiversity not only during the growing season but also in the periods (autumn, winter) between the main crops.

Communication of results included deliverables both for farmers/advisory services and the scientific community (see WP5 and Paragraph 5). Publication of scientific articles will continue after the project.

WP2	Crop mixtures for weed suppression
WP leaders: Anneli Lundkvist & Theo Verwijst (SLU-CPE) Responsible partners: Roman Krawczyk (IOR-PIB), Sylwia Kaczmarek (IOR-PIB)	

Overall summary of main results, discussion and conclusions of WP2

The aim of the studies performed in PRODIVA working package 2 was to assess the weed suppressive ability of crop mixtures (spring barley + peas) compared to the suppressive ability of pure crops. The work was done by means of field trials in which natural weed populations were used while controlled experiments were made with *Elytrigia repens* or *Sinapis alba* as model weeds. Over a period of three years, 5 field experiments and 9 experiments under controlled conditions were conducted in Poland and Sweden.

In all experiments, performance was assessed in terms of the crops ability to compete against weeds (AC). The ability to withstand competition from weeds (AWC) and the relative weed biomass in the intercrop, compared to weed biomass in the sole crops (RWB) was also calculated if data were available. In some of the experiments, a treatment with only weeds was added as a control to assess the effects of crop presence on weeds. In some of the experiments, the leaf area index was measured over time, hypothesizing that LAI and leaf area duration (LAD) would be explanatory traits of importance for weed suppression.

The overall results confirm that sole pea is a weak competitor in comparison to spring barley and that an intercrop of pea and spring barley may have a strong weed suppression. However, the results obtained in this study varied from year to year and from site to site. The performance of an intercrop is difficult to predict in advance and seems to depend on factors such as precipitation, nutrient availability, proportion of intercrop components and actual weed species composition, which all interact. A good crop establishment is essential for weed suppression under all circumstances. The weed suppressive effect of an intercrop is at least for a large part due to shading, and one element which may contribute to the weed suppressive ability of an intercrop is the capacity to maintain a significant leaf area over a longer period than the sole crop components.

Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:
Five field experiments and 11 controlled experiments were performed in Poland and Sweden. From the collected experimental data AC (ability to compete), AWC (ability to withstand competition), and RWB (relative weed biomass) were calculated.

AC, AWC and RWB - Field experiments in Poland and Sweden
Poland – three field experiments (natural weed flora)
Over all years (2015-2017) and harvests (2 harvests), no significant effects of treatments on AC were found in the field experiments, apart from harvest at early stage 2015: Sole barley had the highest AC, pea the lowest, and the inter crop (IC) was intermediate. Those differences, however, had vanished at final harvest. No data were available to calculate AWC. The RWB was variable and did not show significant differences between treatments.

Sweden – two field experiments (natural weed flora)
A very high weed pressure was present in the field in 2016, weed biomass in all treatments making up over 65% of the total biomass. No significant differences in AC could be detected. This was likely due to a negative effect of voles on the crop during early growth. In 2017, the AC of barley was highest, the IC performed intermediate and the AC of pea was lowest. As no weed-free treatments were included in both years, AWC could not be calculated. The RWB, however, displayed in 2016 significant differences between treatments which differed in seeding proportion of pea and barley, an even proportion giving the largest synergistic weed suppression

AC, AWC and RWB - Controlled experiments in Poland and Sweden
Poland – three glasshouse experiments (model weeds: Elytrigia repens, Sinapis alba)
Two harvests were performed in the glasshouse experiments, the first one occurring about one month prior to final harvest at mature crop stage. During none of the early harvests of barley, pea and their IC in which *E. repens* was used as a model weed, significant differences in AC between treatments occurred. In general at this stage the AC was close to 1. However, when *S. alba* was used as a weed, the ability to compete at an early stage was significantly larger for pea than for barley, while the IC was intermediate. At final harvest in 2015, significant differences between treatments were found, AC being larger with increasing proportions of barley in the barley/pea mixtures, when using *E. repens* as a weed. At final harvest with *S. alba* as a weed, the differences in AC between treatments had disappeared. Combining the results obtained with competition from those different model weeds over time, a monocotylodon- and a dicotylodon-species, it is suggested that the competitive balance between crop and weed is affected by time trajectory specific changes in leaf architecture of both weed and crop assemblage. No significant differences between treatments could be detected with regard to AWC during any of the glasshouse experiments. Some of the RWB scores at final harvest were significantly below 1, suggesting a synergistic weed suppression effect of the IC.

Poland – three growth chamber experiments (model weeds: Elytrigia repens, Sinapis alba)
During 2015, the growth chamber experiment with *E. repens* as model weed gave significant differences in AC between treatments, both at an early stage and at harvest. Sole pea displayed the lowest AC at both harvests, while sole barley ranked consistently high. No differences between treatments were detected in AWC and RWB.
When *S. alba* was used as model weed, no differences were found in AC at early stage, but at final harvest the AC for sole pea was significantly lower than for barley and the IC, which is in contrast with the results from the glass house experiment. The IC had a significantly higher AWC than the other treatments when competing with *S. alba* and the RWB was significantly below 1 at both harvests suggesting a strong suppressive effect of the IC on *S. alba*.

Sweden – three box experiment (model weed: Elytriga repens)
AC was high in general (close to 1) and did not differ significantly between treatments within 2015. In 2015, the AC did not differ significantly from 1 (indicating complete weed pressure) likely due to a low initial density of planted rhizomes of *E. repens*. In 2017, pea displayed a lower AC than the IC. In 2017, all differences between treatments were significant, pea having the lowest AC, barley the highest and the intercrop being intermediate. Analysed over all years together, sole pea had a lower AC than both the IC and sole barley.
AWC did not deviate significantly from 1 in any of treatments during any of the years, i.e. no negative effects of weeds on the crop could be demonstrated. This again may be attributed to a relatively low weed pressure in the experiments.
RWB was not significantly different within or over all years, and did not deviate significantly from 1, i.e. no synergistic weed suppression effect of the IC was detected.

Effects of crop presence
The general effect of crop presence on weed biomass at crop harvest was consistently larger in all experiments which contained a crop-free treatment. When including a crop-free treatment as a control, this treatment on average has a weed biomass at crop harvest which was at least five time higher than in treatments with a crop, as an average over all field experiments performed in Poland 2015-2017. This clearly shows the overriding importance of establishing a crop for suppressing weeds. A similar conclusion can be drawn from the Swedish experiments performed under controlled conditions where the crop-free treatment as a control, on average has a weed biomass at crop harvest which was at least ten time higher than in treatments with a crop.

Shading of weeds by crops and intercrop
The weed suppressive ability of a crop by means of shading may be approached by an integration of LAI over time. While being a course approximation, the LAI as measured during several occasions in the season can be summed to obtain a 'relative leaf area duration' (LAD). Pure barley has a relatively low LAD, while sole pea has the highest LAD and intercrops with an increasing proportion of pea are intermediate. This may be one of the reasons for success of an intercrop, if well established.

Additional:
Data from the Swedish box experiment in 2015 were used for a master thesis. The thesis is published and has been uploaded to Organic E-print (Pers. Berglund, 2016).

B- fulfilment of objectives:
The work package ran as planned. Studies on crop mixtures (M2.1, M2.2 and M2.3) were performed and results were analysed. Two reports (D2. and D2.2) have been uploaded to Organic Eprint. A technical report (D2.3 Scientific publication) has also been uploaded to Organic Eprint (not allowed as open access). The results are planned to be published in two scientific publications, see '5.3 Further possible actions for dissemination'.

WP3	Variety mixtures for weed suppression

WP leader: Bo Melander (AU)
Responsible partners: Livija Zarina (AREI), Mette Sønderskov (AU), Sylwia Kaczmarek (IOR-PIB)

Overall summary of main results, discussion and conclusions of WP1

Field experiments with different varieties of spring barley and oat have been conducted in Poland and Latvia in 2015, 2016 and 2017 and in Denmark in 2016 and 2017. The varieties were grown either solely or in mixtures of two, three or four varieties. The purpose was to examine the suppression of weeds provided by the mixtures, to clarify the attributes involved in significant weed suppression and to quantify the impact on crop yield and quality when combining varieties.

In addition to the naturally occurring weed species, an artificial weed, white mustard (*Sinapis alba*), was established in parts of the plots in Poland and Denmark to ensure significant competition between weeds and crops. Generally, the mixtures provided similar weed suppression levels as the single varieties. There were a trend of mixtures combining early growth and ground coverage with extensive height growth to compete better with the weeds. The most promising mixtures, however, were often those containing a competitive variety that was also highly competitive when grown as single varieties, which is in line with previous findings. The same was observed for crop yields that did not differ much among the different single varieties and mixtures studied.

The varieties on the marked in the three countries represent a limited range of the measured characteristics and the results can only indicate a potential for breeding for more variance among the varieties to increase the potential for weed suppression of mixtures.

Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:
Previous works on the suppressive ability of cereal varieties was reviewed in early 2015 before field experiments were designed and established. Most of the literature deals with the suppressive ability of single varieties whilst studies on variety mixtures are scarcer in relation to weed suppression. A very recent review of Andrew et al. (2015) (Weed Research 55, 239-248) scrutinizes the knowledge on variety traits known to be responsible for weed suppressing effects. In the few studies on variety mixtures, it seems that mixtures with traits such as tallness, high early season vigor (high initial growth rate producing abundant biomass) and early maturation have resulted in higher weed suppression than other trait combinations.

Field experiments with variety mixtures were established in Poland and Latvia in 2015, 2016 and 2017, while in Denmark; field experimentation was only conducted in 2016 and 2017. It turned out that varieties commonly used in the three countries were very different and it was not possible to grow exactly the same mixtures in the three countries. The available information on variety characteristics were not the same in the three countries, hence the rational for mixing varieties differed among countries. In Denmark, more detailed information was provided by the breeders and the hypothesis of mixing varieties representing early growth with tall growing varieties were tested in the mixtures. In Poland and Latvia, this information was not available and more random mixtures were made. The recordings of weed and crop growth followed a similar protocol to ease the analyses of results across countries.

The Polish experiment had 6/7 spring barley varieties either grown alone or in 15/21 different mixtures with each mixture consisting of two varieties in a 50 by 50% seed mixture (7 varieties were used in 2017, resulting in 21 mixtures). This resulted in 21/28 treatments and with 4 replicates a total of 84/112 plots were included. The extra variety in 2017 was added as an Austrian variety with increased height growth was included to increase the variance in this characteristic. Three different oat varieties were also studied for their competitive abilities and they were grown either solely or in 3 blends, again with two varieties in a 50 by 50% mixture. With 4 replicates, a total of 24 plots with oat were studied. The competitive ability of the different varieties and blends were assessed on the growth of naturally occurring weeds and the model weed, *Sinapis alba*, was included as well to strengthen the data on weed growth. A number of different parameters were recorded such as crop plant numbers, tillering abilities, stem lengths, LAI (measured 4 times), crop and weed biomasses, weight proportions of leaves, stems and flower stands of selections of crop plants, crop yield and quality. In general, only minor differences were seen among the treatments in terms of their weed suppressive abilities, although a few blends showed some positive trends. Especially varieties that performed well on their own also appeared to raise the weed suppressive ability of the blends in which they were included. Contacts to relevant stakeholders have been established and the experiments and preliminary results have been displayed to different stakeholder groups.

In Latvia, a field experiment was conducted using 4 spring barley varieties either grown alone or in different mixtures; 6 mixtures consisting of two varieties and two mixtures with 3 different varieties. This resulted in 12 treatments and with 4 replicates, a total of 48 plots were established. Three different oat varieties were also studied for their competitive abilities and they were grown either alone or in 3 mixtures, with two varieties in each mixture. With 4 replicates, a total of 24 plots with oat were studied. Similar to Poland, a number of different parameters were recorded in the experiments such as crop plant numbers, different attributes of the varieties, stem lengths, crop and weed coverages, crop yield and quality. In general, and similar to Poland, only minor differences were seen among the treatments in terms of weed suppression. However, some mixtures tended to produce higher yields, particularly when a variety that performed well in pure stand was included in the mixture. Different stakeholder groups visited the experimental site during the growing seasons 2015 and 2016.

Preliminary results from Poland and Latvia were presented at the International Weed Science Congress in Prague in June 2016.

In Denmark, field experiments was conducted with 6 spring barley varieties either grown alone or in different mixtures; 6 mixtures consisted of two varieties, one mixture with three varieties and one mixture with 4 different varieties. Three different oat varieties were also grown alone or in two mixtures with two varieties or in one mixture with three varieties. Totally, with 4 replicates, 80 plots were included. The same Austrian variety with extensive height growth was included as in Poland. In Denmark, however, this variety replaced a variety from the first year and no additional number in varieties was added.
As for Poland and Latvia, there were only few differences among the treatments. There was a tendency for early growth combined with a tall variety to increase weed suppression, but the results were not completely consistent. Again, this was in line with results from Latvia and Poland.

Conclusion: The initial hypothesis of increased weed suppression with mixtures combining early growth and ground cover with tall varieties are partly supported, but not entirely consistent. There was an overall negative correlation between the crop biomass and weed biomass. This should be viewed in a context of a growing strategy where several tools or actions are combined to make the most competitive crop. In a system with limited input, there is no silver bullet and it will be difficult to find a single management practice that can control weeds sufficiently. When farmers choose the varieties for a season they often choose based on disease resistance and yield stability, but weed suppression characteristics can be seen as a third criteria.

B- fulfilment of objectives:
Some general growth characteristics were identified as most important for variety mixtures based on data analyses of three year’s field experiments in Latvia, Poland and Denmark. This information was presented in national catalogues giving general guidelines for variety mixtures.

WP4	Crop diversification and weeds on farms

WP leaders: Bärbel Gerowitt
Responsible partners: Merel Hofmeijer (UR), Livija Zarina (AREI), Bo Melander (AU), Jukka Salonen (Luke), Anneli Lundkvist & Theo Verwijst (SLU)

Overall summary of main results, discussion and conclusions of WP4

Expert knowledge and grey literature on weed species was collected from all participating countries to acquire an overview of most problematic weed species in their local organic agriculture. This provided an insight into the existing knowledge and the weed species of concern. These data were compiled into an expert database and published in a leaflet, now available on Organic Eprints.

Weed data was collected from farmers' fields in all five participating countries over the course of two years (2015-2016). The collected data contain densities of all surveyed weed species in the fields with spring sown cereals including management data of the fields studied. A database has been finalized with both weed and management data. The purpose was to study the relations between crop diversification measures and the diversity of weed species actually present in the fields.

Use of crop diversification measures was different among regions. Previous and current use on the monitored spring cereal fields was low for crop mixtures, but frequent for rotational measures; variety mixtures were not used. Mixed models analyses of species numbers and diversity revealed few influencing factors. Multivariate analyses of the weed communities nevertheless indicated influencing factors, hence the composition of species is shaped by crop diversification measures.

Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:

<u>Ex-ante/Expert database</u>

The expert database was compiled from local (grey) literature and information from expert sources from all PRODIVA partners. The focus was on the most frequent and problematic weed species in their local organic arable agriculture. Especially, the most problematic species occurring in spring sown cereals. This information was compiled into lists for each country. In the process, the database was renamed from 'Ex-ante' into 'Expert', for the former was a cause for confusion. Some interesting results were drawn from this expert database. The first is that there are weed species that prove problematic in all participating countries such as *Chenopodium album*, *Cirsium arvensis* and *Elytrigia repens.* Besides these, every country faces challenges with local specific species, such as *Fumaria officinalis* in Latvia and *Amsinckia micrantha* in Denmark. These local-specific weed problems are possibly caused by local environmental characteristics and specific species dispersal. The results were compiled into a leaflet, which has been published on Organic E-print. The leaflet is available in English. Weed species were grouped in an easily understandable manner. Five weed types with vivid names like e.g. "Bodybuilders", "Zombies" or "Plebians" according to their ability to interfere with organic arable practices were made. The database was further used in WP 5 for national adaptations. Outcome from this collection is compared with actual species found in the field surveys.

<u>Field data collection</u>

Organic farmers were approached with the help of extension services and organic growers organizations for participation in the survey. All partners were successful in attracting farmers and in building fruitful relationships. The following numbers of farms were visited by each partner in 2015 and 2016: Germany: 11 farms, Finland: 15 farms, Sweden: 10 farms, Latvia: 10 farms and Denmark: 25 farms (2015), 10 farms (2016). Poland was not involved in this work package. The polish partner decided to join in the second year and visited 6 fields only in 2016. Finally, the polish data was excluded in the analyses because limited data.

Over the course of two years, 207 fields of spring sown cereals were surveyed in total by five PRODIVA partners for their weed species densities. This was done by estimating the densities of individual weed species found within an area of 100m². Each field had three repetitions and on each farm 1-3 fields of spring sown cereals, such as wheat, triticale, barley and oats, were surveyed this way. The surveys were conducted during the flowering of the crop, anytime between May and August, depending on the local growing season. This was combined with a questionnaire to retrieve the field history and farm management practises for the explanatory variables needed for the analysis. The interviews aimed specifically at gathering information about crop diversification strategies used in field management, for exploring connections to the weeds observed in the fields as well as the experiments running in WP1, 2 and 3. These questionnaires were mostly planned in winter, when farmers were less busy. All farmers involved were obliging and seemed enthusiastic about the collaboration with researchers in both years, and happy to provide the additional field history information. All partners successfully followed the protocol and collected all required data. All data were compiled in one large database for further analysis. This database is internally available.

Results:
The crop diversification strategies used by the farmers as indicated in their farm management and retrieved from the interviews, included undersown crops, winter catch crops and crop mixtures. However, although mentioned in general farm management, none of the field histories showed the usage of variety mixtures in the rotation of the sampled fields. The crop diversity strategies applied, where specific to the country, and possibly due to local geographical and socio-economic factors. For example, winter catch crops were grown in Denmark, Germany and Latvia, but not in Sweden or Finland. The crops chosen were country-specific as well; Denmark and Latvia opted for grass clover mixtures, Germany planted mustard and oilseed rape as catch crop.

During both years, in all countries, on average 25 weed species were found per field, minimum 6, maximum 41. The diversity ranged from 0.56 – 2.79 on the Shannon index. Weed densities encountered were 4 to 536 individuals per m^2. Especially, this last number varied greatly per country. Then weed densities, species numbers and diversity were analyzed country-wise. Densities were found to be lowest in Denmark, and highest in Sweden. On the contrary, species numbers and consequently weed species diversity were found to be relatively equal between countries. The specific weed species found were partly similar and partly specific to the countries, where more frequent species were shared by most countries, such as *Stellaria media*, *Chenopodium album*, *Fallopia convolvulus* and *Elytrigia repens*. Less frequent species were often location specific such as *Galinsoga parviflora*, *Sisymbrium officinale* or *Medicago lupulina*.

The influence of crop diversification strategies on weed density, species numbers and diversity was analysed (using mixed models) for the total international dataset. No effects were found, positive or negative, on weed densities. Crop diversification use in the rotation will not increase the densities found in the field. An effect was found for the use of winter catch crops, which increased both weed species numbers and diversity. Thereafter the effect of crop diversification on the total international weed community was also studied, with the use of multivariate analysis. Here all crop diversity strategies had a significant effect on the weed community. It also reflected the results from the mixed models analyses, as winter catch crops had the most specific effect, increasing winter annuals and negatively impacting some perennial and grassland species.

<u>Additional:</u>
<u>All materials produced in WP 4 have been uploaded to Organic e-print.</u>
The workpackage was presented at the German Weed Science Conference in Braunschweig in February 2016. The workpackage and outcomes of the expert database were presented orally and as a poster at the International Weed Science Congress in Prague in June 2016. WP4 was presented at the German Organic Agriculture Conference (Wissenschaftstagung Ökologischer Landbau) in Freising in March 2017 and at the Nordic Organic Conference in Finland in June 2017. Denmark used the opportunity of the weed survey for

making a master thesis based on the 2015-survey studying the importance of crop diversification 5 years prior to the survey. The thesis is published and has been uploaded to Organic e-print. Polish results from their smaller weed survey of spring cereals were presented during national conference in Poland in 2018 (Sesja Naukowa Instytutu Ochrony Roślin, Opalenica, Poland).

B- fulfilment of objectives:
WP4 was running as planned. Deliverable D4.1 is published. Deliverable D 4.2 is shared by all project partners. The analyses of the survey data (D4.3) are included in the presentation: 'The arable vegetation of Baltic organic cereal fields as shaped by crop management' (Workshop on the European Weed Research Society Congress, Ljubljana, June 2018, uploaded to Organic E-print. Two full scientific publications are on their way.
A comparison and analyses of the surveys and experiments (D 4.4) is made in the presentation: From science to practice and back – knowledge and information chains in PRODIVA (Workshop on the European Weed Research Society Congress, Ljubljana June 2018, uploaded in organic-eprint). A scientific publication is in preparation.

WP5	Dissemination

WP leader: Bärbel Gerowitt (UR)
Responsible partners: Merel Hofmeijer (UR), Livija Zarina (AREI), Bo Melander (AU), Jukka Salonen (Luke), Anneli Lundkvist & Theo Verwijst (SLU), Sylwia Kaczmarek (IOR-PIB), Roman Krawczyk (IOR-PIB)

Overall summary of main results, discussion and conclusions of WP5

Stakeholder networks were set-up in all project regions. The networks were informed about PRODIVA activities. They were used to acquire farmers for the field work in WP4. Regional stakeholder knowledge fed the joint ex-ante/expert data base, which was set-up in English (WP4). Translation and dispersion via regional stakeholder networks. Regional activities took place in the stakeholder networks.

Report on the results obtained (A), and fulfilment of objectives (B)

A- results obtained:
All project partners contacted regional stakeholders. They represent organic farmers, organic advisors and regional or national research partners. The national stakeholder networks are maintained by the partners in the regions and added to the list of PRODIVA-stakeholders. The stakeholder networks were used to set-up and fill the ex-ante data base (see WP4). The expert/ex-ante data base with important weeds relevant to organic arable farming was used for WP5, since it is a good product for the dissemination activities. Project partner Poland was involved from the beginning in WP5. The Expert database is explained in WP4. The leaflet of the ex-ante/expert database was translated into national languages. These leaflets are distributed and shared with farmer's network and national stakeholders.

The stakeholder-network in Mecklenburg-Vorpommern, Germany includes 11 farmers, representatives of grower's organisations like BIOLAND and BIOPARK, and the State Research Organisation for Agriculture of Mecklenburg-Vorpommern, division for Organic farming. Moreover PRODIVA is included in an initiative "Organic Farming in Eastern Germany", in which stakeholder met from all German States in the Eastern part. In Mecklenburg-Vorpommern, the German state in the North-East, PRODIVA was introduced to stakeholders in personal communication on winter meetings and on field days in summer.

The stakeholder-network in Latvia includes 10 farmers, representatives of grower's organisations like Latvian Agricultural Organization Cooperation Council (LAOCC), and Association of Latvian Organic Agriculture. PRODIVA was presented for stakeholders at several field days at AREI.

The Danish network of stakeholders consisted of 25 farmers and advisers at the organic section at the national advisory centre, SEGES, (https://www.seges.dk/raadgivning/find-ekspert/oekologi). Results have been disseminated via farmers magazines, master thesis, meetings and 'the Danish Økologikongres 2017'.

The stakeholder-network in central Sweden includes 10 organic farmers. PRODIVA was introduced to stakeholders in personal communication on winter meetings and on field days in summer. Presentation of final results from all work packages in PRODIVA will be performed for the stakeholder network in the end of July, 2018.

The Polish network consisted mainly of farmers and advisors, but also students and scientists. Information about PRODIVA project and results were presented to network representatives during national meetings with farmers and advisors, national conferences, and also by direct contact with farmers and advisors.

Examples of successful implementation of crop diversification were selected from the national farmers networks. Farmers were questioned about their experiences concerning crop diversification and weeds. The information was communicated via success stories among farmers in order to facilitate knowledge transfer. Descriptions of success stories in national languages are presented in a practical manner. These descriptions are uploaded to Organic E-prints. An overall evaluation of the success stories from five different countries revealed rotation measures (cover crops, crop rotation composition) as being most decisive for weed management, while crop mixtures and especially varieties mixtures were ranked lower for weed management. Weed species mentioned by farmers in the interviews were creeping perennials (Zombies) and strong competitors (Bodybuilders). Some of these species were included in the experiments in WP 1-3. Organic farmers successful in using crop diversification for weed management acknowledge diversity in their weed communities. Arguments supporting this ranged from aesthetic to wildlife aspects.

B- fulfilment of objectives:
The work package ran as planned. The stakeholder-networks were arranged (D 5.1) and the nationally adapted ex-ante databases were delivered to all national stakeholders and via Organic E-prints (D 5.2.) Regional success stories are uploaded via Organic E-print in national languages for six countries (D 5.3).

4. Milestones and deliverables status

Deliverable No.	Deliverable name	Link to the document	Planned delivery month[1)]	Actual delivery month[1)]	Reasons for changes/delay and explanation of consequences
D1.1.	Review on cover crops and crop sequencing	http://orgprints.org/30916/, http://orgprints.org/32510/	24	24 (FIN), 34 (ENG)	Finnish manuscript ready for editing. English version under way, the list of references checked by Partners
D1.2	Stakeholder communication with guidelines for crop sequencing	http://orgprints.org/30647/, http://orgprints.org/30561/	12/24	12/24	
D2.1	Report	http://orgprints.org/33109/	12	18	Analyses of results from an experiment in Sweden were delayed due to sick leave of one of the persons involved in the project.
D2.2	Report	http://orgprints.org/33110/	24	24	
D2.3	Scientific communication	http://orgprints.org/33522/	36	36	
D3.1	Catalogue with	Uploaded to	36	36	

	cereal varieties and variety mixtures	Organic E-print, awaiting approval			
D3.2	Scientific communication	Preliminary draft uploaded to Organic E-print, awaiting approval	36	36	
D4.1	Ex-ante weed database	http://orgprints.org/30635/	12	16	
D4.2	Ex-post weed database	PRODIVA-partners	24	24	
D4.3	Analyses of the survey data	http://orgprints.org/ 33428	32	32	
D 4.4	Comparison and analyses of the surveys and experiments	http://orgprints.org/ 33447	36	38	
D5.1	Stakeholder network set-up	Overview compiled at UR for internal use	12	12	
D5.2	Ex-ante weed database regionally adapted	for example: http://orgprints.org/32598	24	28	
D5.3	Regional success stories	Examples: http://orgprints.org/32511/ and http://orgprints.org/33463	36	39	

Milestone No.	**Milestone name**	**Planned delivery month**[1)]	**Actual delivery month**[1)]	**Reasons for changes/delay and explanation of consequences**
M1.1	Data (DK, LV) and literature on crop sequencing	12	12-30	Additional new data from established experiments
M1.2	Strategies for crop sequencing	20	12-36	Various papers and presentations delivered
M1.3	Cover crop effects (FI, LV)	20	10-36	New data available. Various papers and presentations delivered
M2.2	Second study on crop mixtures	24	24	
M2.3	Third study on crop mixtures	34	34	
M3.1	Variety selection achieved	12	12	
M3.2	First study on mixtures	24	24	
M3.3	Second study on mixtures	34	34	
M3.4	Communication	36	36	
M 4.1	Ex-ante weed database agreed	12	12	
M 4.2	Ex-post weed database	24	24	
M 4.3	Analyses of survey and management data	36	38	
M 5.1	Stakeholder network collected	12	12	
M 5.2	Regional databases	28	28	

[1)] Measured in months from the project start date (month 1)

5. Publications and dissemination activities

5.1 List extracted from Organic Eprints

The list can have these headers: ***http://orgprints.org/view/type/***
Publications that are not allowed as open access should be deposited as "Visible to: Depositor and staff only". The funding bodies and project evaluators will be granted access to these during the evaluation. Guidance on the use of Organic Eprints can be found here: http://orgprints.org/help/ and **a screenshot** manual:
http://coreorganic2.org/Upload/CoreOrganic2/Document/2013_%20Screenshot%20manual_orgeprints.pdf

Number of items at this level: **90**.

Journal paper

Melander, Bo; Rasmussen, Ilse A. and Olesen, Jørgen E. (2016) Incompatibility between fertility building measures and the management of perennial weeds in organic cropping systems. *Agriculture, Ecosystems and Environment*, 220, pp. 184-192.

Newspaper or magazine article

Bech, Gustav and Melander, Bo (2016) Sådan kan du begrænse ukrudtet på økologiske marker. *Organic Today*, 10 December 2016, pp. 1-2.

Melander, Bo (2018) A successful grain crop is the best weed management. *ICROFS news*, 4 April 2018, p. 1.

Melander, Bo (2017) Kløvergræs og afhugning nedsætter ukrudtsmængden. *Økologi & Erhverv*, 2017 (608), p. 6.

Melander, Bo (2016) Lektor: Fem tips til at begrænse ukrudtet i økologiske marker. *Landbrugsavisen*, 14 December 2016, pp. 1-3.

Melander, Bo (2016) Fem tips til at begrænse ukrudtet i økologiske marker. *Maskinbladet dagens landbrug*, 13 December 2016, p. 1.

Melander, Bo (2016) CROP DIVERSITY PREVENTS SERIOUS WEED PROBLEMS. *Core Organic Plus News*, 6 May 2016, pp. 1-2.

Melander, Bo and Theilgaard, Malene (2016) Ukrudtsproblemer kræver større sædskifteforskelle. *Økologi & Erhverv*, 23 September 2016 (596), p. 10.

Salonen, Jukka (2017) Pitkäjänteistä rikkakasvien torjuntaa luomutiloilla. [Persevering weed management in organic farms.] *Kasvinsuojelulehti*, 21 December 2017, 50 (4), pp. 114-117.

Working paper

Hofmeijer, Merel A.J. and Salonen, Jukka (2017) Kevätviljapeltojen haasteellisia rikkakasveja - Katsaus luomupeltojen tilanteeseen Itämeren alueella. [Geographical distribution of challenging weed species - Current knowledge in organic farming in the Baltic sea region (original paper in English language).] Working paper, Management and Production of Renewable Resources, Natural Resources Institute Finland (Luke).

Koppelmäki, Kari; Känkänen, Hannu and Salonen, Jukka (2016) Luomupeltojen rikkakasvien hallinta peitekasvien avulla. Luonnonvara- ja biotalouden tutkimus, no. 65/2016, Management and production of renewable resources, Natural Resources Institute Finland (Luke).

Salonen, Jukka; Koppelmäki, Kari and Känkänen, Hannu (2017) Weed management with cover crops in the Nordic-Baltic region - a snapshot from the references. Working paper, Management and Production of Renewable Resources, Natural Resources Institute Finland (Luke).

Conference paper, poster, etc.

Gerowitt, Bärbel; Hofmeijer, Merel A.J.; Melander, Bo; Krawczyk, Roman; Salonen, Jukka; Verwijst, Theo and Zarina, Livija (2015) Team-up crop diversification and weed management: PRODIVA. Better utilization of crop diversification for weed management in North European organic arable cropping systems. Poster at: 17th European Weed Research Society Symposium, Montpellier, 23-26 June 2016.

Gerowitt, Bärbel; Hofmeijer, Merel A.J.; Melander, Bo; Sonderskov, Mette; Krawczyk, Roman; Kaczmarek, Sylvia; Salonen, Jukka and Verwijst, Theo (2018) From practice to science and back – knowledge and information chains in PRODIVA. Workshop at: 18th European Weed Research Society Symposium 2018, Ljubljana, Slovenie, 17-22.06.2018.

Hofmeijer, Merel A.J.; Gerowitt, Bärbel; Krawczyk, Roman; Salonen, Jukka; Verwijst, Theo; Zarina, Livija and Melander, Bo (2016) Crop diversification for weed management in North European organic arable cropping systems. Introduction to the study of international research-network on diversification and weed management: PRODIVA. Poster at: 7th International Weed Science Congress, Prague, 19-25 June 2016.

Hofmeijer, Merel A.J.; Gerowitt, Bärbel; Salonen, Jukka; Verwijst, Theo; Zarina, Livija and Melander, Bo (2016) The impact of crop diversification management on weed communities in summer cereals on organic farms in Northern Europe. An introduction to the study. In: Nordmeyer, Henning and Ulber, Lena (Eds.) *Julius-Kühn-Archiv*, Berlin, 27, pp. 452-456.

Hofmeijer, Merel A.J.; Melander, Bo; Krawczyk, Roman; Salonen, Jukka; Verwijst, Theo; Zarina, Livija and Gerowitt, Bärbel (2017) Problematic weed species in organic arable agriculture around the Baltic Sea - An expert database. Poster at: 14. Wissenschaftstagung Ökologischer Landbau, Freising, Germany, 7-10.03.2017.

Hofmeijer, Merel A.J.; Melander, Bo; Salonen, Jukka; Verwijst, Theo; Zarina, Livija and Gerowitt, Bärbel (2018) The arable vegetation of Baltic organic cereal fields as shaped by crop management. Paper at: 18th European Weed Research Society Symposium 2018, Ljubljana, Slovenie, 17-22.06.2018.

Kaczmarek, Sylvia (2016) PRODIVA WP 3 Variety mixtures for weed suppression.2015. Speech at: [Completed]

Kaczmarek, Sylvia; Zarina, Livija; Melander, Bo and Krawczyk, Roman (2016) Wykorzystanie potencjału mieszanin odmian owsa jarego i jęczmienia jarego w redukcji zachwaszczenia. [Using mixtures of varieties of spring oat and spring barley for weed suppression.] Speech at: Rola odmiany i ochrony roślin w intensyfikacji produkcji roślinnej, Dymaczewo Nowe, Poland, 11-13.05.2016. [Completed]

Melander, Bo (2017) Sædskifte og afgrødeetablering -sådan undgår du opformering af ukrudt. In: *Plantekongressen 2017*.

Melander, Bo (2016) Rodukrudtsbekæmpelse i økologisk jordbrug i Danmark. Avslutningsseminar, Økokorn 2012-2016, 27. oktober 2016. [Completed]

Piliksere, Dace and Zarina, Livija (2017) Spring cereal variety mixtures and their relevance for weed suppression in agroecological conditions of Latvia. Poster at: Joint workshop of the EWRS working groups: Physical and cultural weed control and Crop-weed interactions, Nyon, Switzerland, 2 – 5 April 2017. [Submitted]

Salonen, Jukka (2018) Weed management in cereals with cover crops - do they help of hinder? In: Simoncic, Andrej (Ed.) *Book of Abstracts - 18th European Weed Research Society Symposium*, Kmetijski Institut Slovenije, Ljubljana, p. 130.

Salonen, Jukka (2016) Manipulating plant species diversity with cover crops - enhancing both biodiversity and weed management in cereals? In: *Proceedings of 6th Workshop of the EWRS Working Group "Weeds and Biodiversity"*, European Weed Research Society (EWRS), Riga.

Salonen, Jukka (2016) Luomuviljan rikkakasvit kiinnostavat tutkijoita, viljelijöitä ja neuvontaa. In: Jalli, Heikki (Ed.) *Kasvinsuojelupäivä*, Kasvinsuojeluseura ry, Jokioinen, pp. 31-32.

Salonen, Jukka; Hofmeijer, Merel A.J.; Zarina, Livija; Krawczyk, Roman; Verwijst, Theo and Melander, Bo (2018) Viljelijöillä tärkeä rooli rikkakasvikartoitusten partnerina. In: Jalli, Heikki (Ed.) *Kasvinsuojelupäivä 2018*, Kasvinsuojeluseura ry, Jokioinen, p. 30.

Salonen, Jukka; Hofmeijer, Merel A.J.; Zarina, Livija; Krawczyk, Roman; Verwijst, Theo and Melander, Bo (2018) Farmers deserve credit for contributing to the weed surveys. Paper at: Maataloustieteen päivät 2018, Helsinki, 10.-11.01.2018.

Salonen, Jukka and Känkänen, Hannu (2018) Aluskasveista apua luomuviljan rikkakasvintorjuntaan? [Any help from cover crops for weed management in organic cropping of cereals?] In: Puhakainen, Tuula and Hakojärvi, Mikko (Eds.) *Maataloustieteen Päivät 2018*, Suomen Maataloustieteellinen Seura, Helsinki, Suomen Maataloustieteellisen Seuran Tiedote, no. 34, p. 27.

Salonen, Jukka and Känkänen, Hannu (2016) Luomuviljan rikkakasvit hallintaan aluskasveja viljelemällä? In: Jalli, Heikki (Ed.) *Kasvinsuojelupäivä*, Kasvinsuojeluseura ry, Jokioinen, pp. 39-40.

Salonen, Jukka and Känkänen, Hannu (2016) Luomuviljan rikkakasvien hallinta aluskasveja viljelemällä. In: Alakukku, Laura; Schulman, Nina and Puhakainen, Tuula (Eds.) *Maataloustieteen Päivät 2016*, Suomen maataloustieteellinen seura, Helsinki, Suomen maataloustieteellisen seuran tiedote, no. 32, p. 161.

Salonen, Jukka; Melander, Bo; Gerowitt, Bärbel; Lundkvist, Anneli; Verwijst, Theo; Krawczyk, Roman; Kaczmarek, Sylvia and Zarina, Livija (2016) Crop diversification and weeds in organic cereal production. In: *Maataloustieteen Päivät 2016*, Suomen Maataloustieteellinen Seura, Helsinki, Suomen Maataloustieteellisen seuran tiedote No 32, no. 32, p. 161.

Salonen, Jukka and Zarina, Livija (2017) Potential of cover crops for weed management in organic cropping. In: Aakkula, Jyrki; Hakala, Kaija; Huhta, Harri; Iivonen, Sari; Jurvanen, Ulla; Kreismane, Dzidra; Land, Anita; Lähdesmäk, Merja; Malingen, Matti; Mikkola, Minna; Nordlund-Othen, Janne; Nuutila, Jaakko; Peetsmann, Elen; Piskonen, Sirpa; Rasmussen, Ilse A.; Skulskis, Virgilijus; Tahvonen, Raija; Taskinen, Sirpa; Ullvén, Karin; Wibe, Atle and Wivstad, Maria (Eds.) *NJF Seminar 495 - 4th organic Conference: Organics for tomorrow's food systems, 19 - 21 June 2017, Mikkeli, Finland*, 13 (1), NJF Report, pp. 33-34.

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Salonen, Jukka; Zarina, Livija and Melander, Bo (2016) Cover crops in cereals – better companions than weeds? In: *Proceedings of the 7th International Weed Science Congress*, Czech University of Life Sciences Prague, Kamycka 129, 16521 Prague 6 – Suchdol, Czech Republic, p. 639.

Sønderskov, Mette; Melander, Bo; Kaczmarek, Sylvia and Zarina, Livija (2018) Can variety mixtures of spring barley benefit weed management? In: *Book of Abstracts - 18th European Weed Research Sciety Symposium*.

Verwijst, Theo; Lundkvist, Anneli; Krawczyk, Roman and Kaczmarek, Sylvia (2018) Prodiva project - Crop species mixtures for weed suppression. In: *New approaches for smarter weed management - Book of abstracts*, European Weed Research Society (EWRS), Kmetijski inštitut Slovenije, p. 41.

Zarina, Livija; Gerowitt, Bärbel; Melander, Bo; Salonen, Jukka; Krawczyk, Roman and Verwijst, Theo (2015) Crop diversification for weed management in organic arable cropping systems. In: *Proceedings of the 10 th International Scientific and Practical Conference*, Rezekne Higher Education Institution, Rezekne, 2, pp. 333-336.

Zarina, Livija; Kaczmarek, Sylvia and Melander, Bo (2016) Mixtures of varieties of spring cereals for weed suppression in organic crop production. In: *Proceedings of the 7th International Weed Science Congress*.

Zarina, Livija; Piliksere, Dace and Zarina, Liga (2016) UNDER-SOWING EFFICIENCY FOR WEED MANAGEMENT IN SPRING CEREALS. In: *Proceeding*, Jelgava, pp. 111-115.

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Zarina, Livija; Vaivode, Aija and Zarina, Liga (2016) Weed biomass in cereals depending growing in pure stand or mixtures. [NEZĀĻU BIOMASA VASARĀJU LABĪBĀS ATKARĪBĀ NO ŠĶIRŅU AUDZĒŠANAS TĪRSĒJĀ VAI MAISĪJUMOS.] In: *Proceedings of the Scientific and Practical Conference Harmonious Agriculture*, Latvia University of Agriculture, Jelgava, LATVIA, pp. 220-223.

Zarina, Livija and Zarina, Liga (2017) VIRSAUGĀ SĒTU VASARĀJU LABĪBU EFEKTS NEZĀĻU IEROBEŽOŠANĀ: PROJEKTA PRODIVA MONITORINGA REZULTĀTI BIOLOĢISKAJĀS SAIMNIECĪBĀS. [The effects of cover crop species in the control of weeds:monitoring results from project PRODIVA.] In: *Proceedings*, Latvia University of Agriculture, Jelgava, pp. 168-169.

Zarina, Livija and Zarina, Liga (2017) Effect of crop rotation on soil nutrient balance and weediness in soddy podzolic organic farming fields. In: *Geophysical Research Abstracts*, Vol. 1.

Report

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5.2 Additional dissemination activities

all dissemination activities are uploaded to Organic Eprints

5.3 Further possible actions for dissemination

List publication/deliverables/activities arising from your project that you are still planning in the future

WP 2

Two scientific publications are in preparation:

Verwijst T, Lundkvist A, Per Berglund A, Krawczyk R, Kaczmarek S. Weed suppressive ability of crop mixture in organic farming. To be submitted to Weed Research.

Verwijst T, Lundkvist A, Krawczyk R, Kaczmarek S. Weed suppressive ability in crop mixtures – a comparison between different cropping systems. To be submitted to Weed Research.

WP 4

Two scientific publications are in preparation:

Hofmeijer M.A.J., B. Melander, J. Salonen, A. Lundqvist, L. Zarina, B. Gerowitt. *Impact of crop diversifications strategies on weed diversity in organic cereals in northern Europe* – to be submitted to European Journal of Agronomy

Hofmeijer M.A.J., B. Melander, J. Salonen, T. Verwijst, L. Zarina, B. Gerowitt. '*Weed species composition explored by the trait associated response to crop management.*' 50% completed - all data collected and structured – to be submitted to Agriculture, Ecosystem and Environment

WP 5

A scientific publication is in preparation:

Hofmeijer, Melander, Krawczyk, Salonen, Verwijst, Zarina, Gerowitt: From practice to science and back – transfer of knowledge and information in a supra-national project about crop diversification and weed management in Organic farming – to be submitted to Organic Agriculture.

Another stakeholder publication in German is on its way:

Wie Vielfalt beim Unkrautmanagement im Öko-Landbau hilft? Praktische Beispiele aus Mecklenburg-Vorpommern – Land-Inform (September 2018)

5.4 Specific questions regarding dissemination and publications

- Is the project website up-to-date? Yes

- List the categories of end-users/main users of the research results and how they have been addressed/will be addressed by dissemination activities

Stakeholder networks (farmers, advisors, educators) were set-up in every participating country. In a transdisciplinary approach, these stakeholders are integrated in all important research steps by bilateral feedback between them and the researcher.

Communicated in a stakeholder-friendly way (national language, adapted to regional situations observed and analysed from surveys on farmer fields), experimental results widen the focus on more and other crop diversification options. A project leaflet describing the key concepts and expected results of the project was produced. The researchers presented results at farmers field days and meetings and participated in national and international workshops and conferences with presentation of PRODIVA results (EWRS-symposium Montpellier 2015; Intern. Scientific Practical Conf 'Environment. Technology. Resources- Rezekne, 2015; Scientific Practical Conf. Harmonious Agriculture - Jelgava 2016; IWSC-symposium Prag 2016; German Weed Science Conference 2016; EWRS workshop Weeds and Biodiversity Riga 2016; German Conference on Organic Agriculture Freising 2017; Nordic Organic Agriculture, Finland, 2017; German Weed Science Conference 2018, 18th EWRS symposium Ljubljana 2018; Plantekongres 2017, Herning, Denmark; Økologikongres 2017, Kolding, Denmark; Polish national conferences: 1.„Rola odmiany i ochrony roślin w intensyfikacji produkcji roślinnej, 11-13.05. 2016, Dymaczewo Nowe, Poland; 2.,,Rolnictwo ekologiczne – stan obecny i perspektywy rozwoju", 5-7 10. 2016, Puszczykowo, Poland; 3.VII Konferencja Naukowa PTA ,,Bioróżnorodność - nowe wyzwanie dla rolnictwa w Polsce", 11-

13.09.2017, Rzeszów, Poland; 4.Sesja naukowa Instytutu Ochrony Roślin, 6-8.02.2018, Opalenica, Poland).

Impact of the project in relation to main beneficieries of the project results.
PRODIVA reached regional stakeholders from practical farming. Organic farmers and advisors know about PRODIVA activities and were keen to hear about results. Dissemination activities were successful.

PRODIVA is also well-known in the European and international scientific community of weed researchers. PRODIVA activities fostered further international cooperation of the partners in scientific proposals and publication activities.

6. Project impact

PRODIVA scrutinized the literature, conducted field and semi field experiments and surveyed 20x fields with spring cereals across five partner countries to provide a stronger foundation for assessing crop diversification as a tool for weed management in organic cropping systems. Crop sequencing in the meaning of pertinently deciding which crops in a sequence of years should be grown to hamper the growth of noxious weeds was the strongest method among the diversification methods studied in PRODIVA. In line with the hypothesis 'that well-thought crop sequencing can mitigate noxious weeds', analyses made in WP1 have revealed the impact of crop diversification combined with physical control actions. The effects on noxious perennial weeds were documented and comprehensively communicated to scientific audiences (e.g. 18th EWRS symposium Ljubljana 2018) and practioners (e.g. Nordic Organic Agriculture, Finland, 2017) as mentioned under item 5.4 and via the uploaded documents in Organic E-print.

It was hypothesised that 'improved cover crop establishment with selected competitive cover crop species' would benefit weed management. The cover crop experimentation in Finland and Latvia have surely supported this hypotheses and the more long-termed consequences of cover cropping in cropping systems have been assessed by analysing Danish data with a longer history. The work in WP1 was finally condensed into five basic rules for weed management for organic growers to follow. These rules were mainly communicated to practitioners and their advisers (e.g. Plantekongressen 2017 and http://orgprints.org/30943/).

The two hypotheses suggesting that 'crop mixtures utilizing the resources better than sole crop species would result in more weed suppression' and that 'variety mixtures exert a stronger pressure on weed development than the sole varieties' were not clearly supported. Both WP2 and WP3 did not result in any significant and unambiguous effects suggesting that weed suppression should be the first priority when considering crop or variety mixtures. This is an important message to practise as it can erase wrong perceptions among farmers. However, when interviewing the many farmers involved in the weed survey in WP4 it became apparent that yield preservation and disease control were the two major reasons for the use of mixtures.
The work on crop species mixtures did not result in any recommendation to practice. The science did not provide clear and consistent information that could be formulated into useful guidelines on how to mix crop species for weed suppression purposes. The same applies to the variety mixtures where consistent results were really not seen. Nevertheless, we have provided some guidance to practice in a small catalogue (http://orgprints.org/33548/) written in both Danish and English. It is planned that the catalogue should also be written for the Polish and Latvian results and be uploaded to organic e-print. Apart from that the results will be presented at growers meetings and in popular articles.

The weed survey in WP4 and all the interactions with the farmers involved provided a very fruitful insight into farmer's behaviour in relation to weed management. Although data from the survey are still to be analysed, there are no strong correlations between the crop diversification methods identified and the actual weed flora surveyed in the fields in terms of species and abundance. It could imply that there is room for more and stronger crop diversification and/or that crop diversification measures are easily overshadowed by other factors such as farmer's skills and specific site characteristics.

In general the partners in PRODIVA believe that the project had strong outreach to the organic farming community which we have documented via the uploaded Organic E-print items. Especially in North-Eastern Germany where farmers asked for the leaflet about the geographical distribution of weeds in the Baltic area. The easy named weed groups were directly taken-up by them when explaining their weed problems and they appreciated the mentioning of weed species being beneficial to agroecosystems. PRODIVA also reached the scientific weed research community of Europe. All project partners used the dissemination chain via the European Weed Research Society (EWRS). A workshop about PRODIVA was accepted for the 2018 EWRS-symposium. The workshop with an introduction and five presentations gave a comprehensive overview of the results and it was attended by approx. 100 participants from 40 different countries.

PRODIVA has provided information and recommendations about crop diversifications measures that can benefit weed management. It has also pointed to those measures (crop species mixtures and variety mixtures), which are perceived among growers to be more suppressive against weeds than sole crops, but which were not convincing in this regard according to our results. Improved weed management leads inevitably to better and more stable crop yields. This helps the supply of organic products to an increasing organic market and it promotes carbon sequestration; the uptake of more carbon dioxide mitigates climate change. An extension of cover crop growth reduces nutrient leaching and thereby supports the prevention of eutrophication of fresh waters and coastal waters. A greater crop diversity in organic cropping systems leads to a more diversified weed flora and fauna, which is in line with UNs convention on biodiversity.

7. Added value of the transnational cooperation in relation to the subject

Research and development efforts in weed ecology and weed management in organic farming are carried out in small research communities, scattered in several countries. PRODIVA has clearly merged expertises who have jointly inspired one another and synergistically produced data, experiences and knowledges that otherwise would not have emerged should the partners themselves have done it. The best example of this is the weed survey in WP4 that has produced rare and valuable data that was really lacking apart from the Finnish situation. Often researchers and advisers have been asked about the weed situation in organic fields and with the PRODIVA work in place, scientifically founded statements can now be given. Also the experimentation conducted in WP2 and WP3 has yielded data with far more comprehensiveness considering the number of sites, especially in WP3, and thereby made it possible to make conclusions on more solid grounds.

PRODIVA has proved the benefits of gathering expertise to maintain and increase the competitive quality and relevance of research. Also the available knowledge base, practises and experiences in the participating countries are complementing each other. By bringing together relevant leading North European expertise on weed ecology and weed management, PRODIVA has addressed the issues needed to add more diversity to organic cropping systems in order to balance weed populations and reduce the needs for direct control actions. By this, perceptions among growers can be either supported or rejected depending on the specific actions that are considered for employment.

The group of scientists focussed on synthesizing knowledge from terminated and ongoing research projects including new experiments on crop rotation, cover crop growing, and variety and crop mixtures. This knowledge has provided a coherent picture and has helped closing important knowledge gaps that exists when using national data only. PRODIVA interacted with partners from farming practice and extension services in organic agriculture and helped identifying best practises, for example the strength of pertinent crop sequencing versus crop and variety mixtures. Regional fields were surveyed for weeds to safeguard the relevance of the experimental research. Current cropping practices and their relations to weed pressure and weed diversity were identified together with the on-farm implementation and future potential for further diversification of the cropping systems. Moreover, the project involved relevant stakeholders from the participating countries. Scientific and applied papers were, and will be, produced to support further development and research into sustainable and diversified North European organic crop production systems.

The combined effort across countries was very effective and bridged a lot of knowledge of diverse nature ranging from technical procedures, experimentation, protocols and ways to establish networks and stimulating the interaction with stakeholders.

8. Suggestions for future research

Crop diversification in crop sequences has proven its value in mitigating noxious weed problems. This information is not novel but it stresses the need to benefit more from diversification of crop rotations especially the advantages of having perennial crops in the rotation. Growers are often reluctant when it comes to growing grass-clover if there is no immediate use of the plant material. They tend to grow annual legume cash crops, which do not provide the same weed controlling effect as grass-clover lasting for two years or more would do. It is important for the organic sector to communicate more effectively the beneficial attributes such as fertility building and weed control linked to perennial leguminous crops. Research should explore more the potentials of growing other perennial crops such as perennial energy crops and / or crops for protein production and utilisation. The inclusion of such perennial crops in organic crop rotations would disrupt the life cycles of many pests.

Cover crops have great importance for preventing nutrient losses and adding carbon to the soil. Methods of establishment and cover crop species clearly affect weed suppression. In practise, many cover crop mixtures often have more than four different species in the mixtures. The reasoning for those mixtures is mostly not scientifically grounded but relies on experience, perceptions and expectations. Thus, more science is needed to understand and utilize cover crop mixtures and their impact on weed control and cropping systems. The control of *Elytrigia repens* is still a challenge with cover crops – also with perennial green manures such as grass-clover. Cover crops hinder the use of tillage to disintegrate and exhaust *E. repens* rhizomes, which suggests that actions that weaken *E. repens* rhizomes prior to cover crop growing would benefit its control strongly. For example, mechanical uprooting and collection of rhizomes before cover crop establishment could potentially lower *E. repens* infestations before periods with cover crops.

Variety mixtures of spring cereals had limited value for weed suppression. It is believed that breeders should value more variation in traits such as stem lengths, tillering abilities and leave orientation in breeding programs. Currently, variety attributes are simply too alike for variety mixtures to really have an impact on weed suppression in comparison to sole varieties.