Locally adapted cereal cultivars in organic farming; for quality in production and product

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Summary

Consumer demand in Sweden as well as in many countries around the world is increasing as related to quality food, including organically produced food. For quality food, both the issues of how the crop has been grown, i.e. in a resource effective way and without for the environment harmful use of chemicals, and what nutritionally and health related values the food holds, has increased in importance lately. Further, transportation of food as related to a desire to consume locally produced food is an issue as well for the consumers. Thus, the aware consumer often prefers locally and organically produced food also with added value in terms of highly nutritious food that adds to health. Organically produced food is of interest for those consumers of several reasons; it is thought to result in a more balanced cultivation of crops with improved plant nutrition values and lower energy consumption and decreased negative climatic influences. Within the hereby reported project, we aimed at increasing the option for sustainable cultivation of locally adopted cereals through organic cultivation. Five different localities was used for the cultivation and our material was included as part of the normally used crop rotation systems at each farm, mostly stable manure was used. The plant material (50 varieties at each place, 10 of these was the same for all localities) was evaluated as related to adaptation and performance on each of the localities by the use of grading of overwintering capacities, growth rhythms, and diseases. Further, the quality of the cultivars was evaluated using protein content, thousand kernel weight, volume weight and essential minerals was analyzed on a smaller number of samples (still ongoing for the large set of sample). The results showed large variation in the analyzed characters among years, localities and varieties. Generally the material showed good resistance to weeds, diseases and pests, maybe mostly because of the growth development rhythm of the material and of the fact that it was a diverse material with a large number of various genetic backgrounds giving also protection against diseases and pests. Yield was mostly influences by genotype although it was sometimes reduced by poor drainage systems and harsh weather in some localities. Protein content was closely and negatively related to the yield. Interesting varieties as related to yield on all localities were the spring barley varieties Ingrid and Gotlandskorn, the spring wheat variety Dragon and the Oats varieties Virma and Engelbrekt. Most interesting from a minerals point of view (although only few varieties are still analyzed) were the winter cereals Svartemmer, speltvete Gotland and borstvete Gotland. Analyses of nutritional values of the produced locally adapted cereals are still ongoing and will add to the value of the hereby reported project.

Sammanfattning
Konsumenter i Sverige och i världen efterfrågar i allt högre grad kvalitetslivsmedel, inkluderande livsmedel baserade på ekologiskt odlade grödor. De kvalitetslivsmedel som efterfrågas är både de som odlats med lägre insatser, tex ekologiskt odlade livsmedel, men också kvalitet i form av närodlade, nyttigare och näringsrikare livsmedel. Sammanfattningsvis så föredrar den medvetne konsumenten lokalt och ekologiskt producerade livsmedel som också bidrar till ett ökat intag av näringsriktig mat och ökad hälsa och välbefinnande. De ekologiska livsmedlen är av stort intresse då de syftar till en mer balanserad odling med förbättrad växtnärings-, och energihushållning och en minskad klimatpåverkan. Inom det här rapporterade projektet syftade vi till ökade möjligheter för hållbara lokalanpassade stråsädessorter genom ekologisk odling. Fem odlingsplatser spridda i Sverige har använts för fältförsök. Den växtföljd som respektive gård tillämpar har använts, i allmänhet ingår användandet av stallgödsel. Växtmaterialet (50 sorter på vartdera stället, och 10 av dessa var desamma på de olika ställena) har utvärderats i form av gradering gällande övervintring, tillväxtrytmer, sjukdomar. Vidare har kvaliteten hos sorterna utvärderats genom analyser av proteinhalt, tusenkornvikt, volymvikt och ett fåtal av sorterna har också analyserats för essentiella mineralämnen (analyser pågår för närvarande på hela materialet). Resultaten visade på stora variationer för de analyserade parametrarna både med avseende på odlingsår, odlingsplats, och sort. Generellt sett så uppvisade materialet bra resistens mot ogräs, sjukdomar och insektsangrepp, kanske framför allt pga tillväxtrytmen hos materialet och genom det faktum att materialet var så pass diverst och att det hade så olika genetisk bakgrund att det faktiskt skyddade sina grannar inom försöket mot angrepp. Avkastningen påverkades framför allt av sorten men var ibland också reducerad pga dåliga dräneringssystem på odlingsplatsen och tuffa väderomständigheter på vissa odlingsplatser och under vissa år. Proteinhalten var negativt och nära korrelerad till avkastningen. Sorten med god avkastning på flera olika lokaler och under flera år var vårkornsorterna Ingrid och Gotlandskorn, vårvetesorten Dragon och vårhavresorterna Virma och Engelbrekt. Mest intressanta sorter ur mineralnäringsämnes synpunkt var (fler sorter behöver analyseras innan större slutsatser kan dras) vintersorterna Svartemmer, speltvete Gotland, och borstvete Gotland. Analyser för att säkerställa nutritionella värden hos de lokalt producerade och adapterade stråsädessorterna inom detta projekt pågår alltjämt och när dessa analyser är klara (inom ett annat projekt) kommer dessa resultat att ge ett mervärde till det härmed rapporterade projektet.

Background
Consumer demand for organic food has increased during later years. The market for certified organic agricultural products has grown from 1.5-2.5% of total food sales both in North America and the EU (Willer and Yussefi 2005, Oberholtzer et al 2005). Factors that affect the purchase of organic food may vary from region to region and country to country. However, ideas of pesticide residues in food have been found more important for the decision than concerns for the environment as a whole, although the later factor is more important in some countries (Byrne et al 1992). The main environmental issue that promotes organic farming is the global warming. Chemical fertilizers, pesticides and herbicides all might have harmful impact on the atmosphere and might also be linked to the global warming. Conventional agriculture relies heavily on these chemicals, which are thought to disturb eco-system as they may enter our soil and seep into our water supplies.

Cereals are generally important crops for food production, wheat being the most commonly grown crop, to a large extent being used for food production, thereby being the most important crop in the world. It nourishes more people than any other crop (FAO data base, 2004). Wheat is used for making food products like bread, pasta, crackers etc, although it might also be used for nutritional high-value whole-grain products. Generally, whole-grain products are among the most interesting alternatives for high value nutritional food from cereals.

Domestication of wheat started 10,000 years ago with cultivation of einkorn (diploid wheat with seven chromosomes pairs). Later tetraploid wheat known as emmer and durum evolved (Heun et al 1997). Common wheat, which is used to make a wide variety of products today, is hexaploid. Bread making goes back to prehistoric time, when seeds from a mixture of grasses were ground into a crude form of flour, to which water was added to form dough (Patient and Ainsworth 1994). The term’ bread’ is used to describe a wide range of products with different shapes, sizes, crusts, textures, colors, softness, eating qualities and flavors (Cauvain, 2003). Barley was domesticated simultaneously as was wheat (Bothmer et al 2003). A number of landraces have been developed over the years since domestication due to locally adapted agricultural practices and natural selection (Jaradat et al 2004). Both oats and rye has been found as a contaminating weed in archaeological records of wheat and barley. Oats was first found as a cultivated crop to a significant level at the end of prehistory in northern Europe (Moore-Colyer 1995).

Statistical information about organically grown cereal in the world is limited. International Federation of Organic Farming Movements (IFOAM) is supposed to calculate the area under organic cultivation worldwide. The area of Europe under organic production was at the time for this application 4.2 million hectares out of which 3.8 million hectares located under European Union (EU). More than 2/3 of EU arable organic production is located in Italy (32%), Germany (25%) and Austria (11%). About 27% of the EU organic cereal production is from Denmark, Finland and Sweden (Yussefi and Willer 2003).

Cereal seed-storage proteins represent an important source of energy, being also involved in determination of bread-making quality in wheat (Cooke and Law 1998). The cereal grain and its milled fractions are known to be important sources of minerals for man and livestock (Iskander and Murad 1986). Further, cereals, fruits and vegetables are major sources of antioxidants and there are hundreds of beta carotene, vitamins and trace elements with antioxidant activity and potentially, beneficial effect on human health by providing defense against oxidative damage (Miller et al 2000).

Bread-making quality is to a large extent influenced by environmental conditions including organic farming (Johansson and Svensson 1998, Hussain 2009). Locally adapted cultivars selected for quality criteria under local organic cultivation conditions might be one way to overcome the problems with not sufficient bread-making quality in organic production. Organic and conventional farming have a great effect on mineral contents of wheat grain. Substantial variation in content as well as extraordinary high values of minerals was found in different types of wheat grown under organic conditions in Sweden (Hussain et al 2010), giving opportunities for breeding and production of high mineral cultivars for organic cultivation. Choice of preferable cultivars for organic cultivation might be one way of producing cereal with high contents of antioxidants. Locally adapted cultivars are thus a potential source of traits for improved nutrition of cereal crops, particularly antioxidants, phenolics in general, carotenoids and tocol in particular. However, as shown by Hussain et al (2010), they also have the potential to improve mineral content, particularly iron and zinc. Locally grown cereal cultivars as well as landraces have increasingly been replaced by modern cultivars which are less resilient to pests, diseases and abiotic stresses. By this, a valuable source of germplasm for meeting future needs of sustainable agriculture in a change climate is lost but also option for locally adapted cultivars for organic cultivation is lost (Newton et al 2010). Landraces and older genetic material, nowadays mostly stored in genebanks are optional sources for production of locally adapted cultivars that can be used for sustainable organic cultivation of quality food products. Traits that can be found in landraces and that can be used in production of locally adapted cultivars for organic production are (Newton et al 2010);

i) Their complex ancestry giving opportunity to variation in response to many stresses,
ii) Large variation in morphological, agronomic, and biochemic traits,
iii) Opportunities to find a high extent of nutrient use efficiency in the material, an important criterion for sustainability,
iv) A large source for improved content of nutritionally important traits in the cereal grain,
v) Valuable sources of resistance to pathogens,
vi) Potentials of having tolerance of pests and abiotic stresses, including toxic environments,

The locally adopted plant breeding has long tradition in Sweden with local plant breeding stations (Olsson 1998). Landraces and old wheat cultivars have within those breeding activities been shown to have a large genetic variation and adaptation potentials towards local growing conditions (Olsson 1997). Research projects related to locally adapted cultivars have been ongoing since 1996 in Alnarp (Larsson 2006) in collaboration with ”Hushållningssällskapen” in Halland, Bohuslän and Gotland. Nordic cooperation has also been present within the project ”Nordiskt korn”. Collaboration with Heinrich Grausgruber at Boku in Austria has been established, where similar projects as the one hereby applied is ongoing (Grausgruber 2004). Within a PhD-project, proteins, minerals, heavy metals and antioxidants were analyzed in organically grown wheat (Hussain et al 2009, 2010, 2011). A joint picture related to the potential cereal cultivars that can be used for different types of and locally adopted organic production, from a quality cropping and food perspective is lacking. The hereby reported project had the aims to contribute with such a joint picture, as well as to provide local growers with recommendations related to organic production of cereals for high value and nutritional important food crops.

The aim of this project was thus to grow potentially attractive old cereal cultivar material with large genetic diversity, selected from experiences of earlier projects. The aim was further to evaluate the material in four different local environments as related to resistance against weeds, pests and insects, nitrogen use efficiency and nutritional content in the grain. Thereby the main aim was to be able, from this project, in combination with results from other projects, to make local recommendations as to use of cultivars for quality organic production of quality food products.

Hypothesis for the project

By the use and evaluation of locally adapted cereals it is possible to select cultivars for organic farming that combines; 1) Good resistance against weed, pests and insects, 2) Good nitrogen use efficiency that contributes to uptake of the nutrients in the soil, plant nutrition economy and reduces nitrogen leakage, as well as 3) High nutritional content in the grain and good quality for making bread or other food products with added value.

Materials and methods

- Selection of cultivars: For each of the localities, 25 spring cultivars and 25 winter cultivars of old cultivar material and with large genetic diversity were selected. Five of the spring and four of the winter wheats selected were the same for all localities in order to have comparable standards over the localities. The genotypes that were the same over all the four localities were; spring varieties: Jusso (rye), Virma (oats), Ella (wheat), Diamant brun (wheat), Engelbrekt (oats); winter varieties: Winter rye (rye), T. monococcum (wheat), Svart emmer (wheat), Speltvete Gotland (wheat), Oberkulmer (wheat). The cultivars that were selected came from the species; einkorn, emmer wheat, spelt wheat, bread wheat, barley, naked barley, white oats, black oats, winter rye and spring rye.

- Cultivation: Five localities was selected to represent different types of local climates in Sweden within the areas were cereals normally are grown in Sweden and also due to the reason that organic farming is already present at the four localities – Alnarp and Ekhaga (both spring and winter trials), Krusenberg and Ekhaga (spring trials) and Vallstena (winter trials). The material will be grown in four repetitions over three years. The cultivations will be part of the normal crop rotation system at each farm.

- The cultivars were evaluated on field as to yield, overwintering, growth rhythms, resistance towards weed, pests and insects etc.

- The cultivars were also evaluated in lab as related to protein, thousand kernel number, and volume weight.

- Essential minerals were evaluated in six of the spring and winter genotypes respectively from the first year of the field experiments in the present project. At present, all minerals are evaluated in the full set of samples within a new follow-up project of the one reported here with funding from Ekhaga. Within the follow-up project, also some bioactive compounds will be analyzed. Furthermore full-grain bread quality of the genotypes is analyzed in another follow-up project in which protein quality will also be evaluated.

Results

Yield

The yield varied over year and location mostly due to weather variations but also due to some problems with drainage and crop rotation systems. Highest mean yields for spring cereals were obtained in Alnarp and Lövsta with 41-46 dt/ha for the barley varieties Alva, Lina, Gotlandskorn and Rika, Ingrid, Gotlandskorn, respectively. Also, the wheat variety Dragon resulted in such high yields in Alnarp. Furthermore, the oats varieties Virma, Engelbrekt, Selma in Alnarp, Engelbrekt, Blenda in Lövsta, Virma in Ekhaga and the wheat varieties Ella, Algot, Walter in Alnarp, Kärn, Lantvete Salarna, Lantvete Hallands resulted in 36-39 dt/ha. Additionally, the wheat varieties vårspelt, våremmer, Prins, Dragon in Lövsta, Dacke, Prins, Ella in Ekhaga, the oats varieties Virma, sommarhavre Gotland in Lövsta, Sol, Sisu Engelbrekt in Ekhaga, and the barley varietites naket 2radskorn in Lövsta, Ingrid in Krusenberg yielded 34 dt/ha. Highest mean yield for winter cereals were obtained for Oberkulmer and Starke in Ekhaga (48 dt/ha), Starke in Alnarp (46 dt/ha) and Hansa brun, Jacoby, Svale, Odin, Aura, Ure in Ekhaga (42-44 dt/ha) and for Holger, Walde, Odin, Eroica, Oberkulmer, Holger brun, Aros, Svale, Sol in Alnarp (41-43 dt/ha).

Overwintering
The overwintering of the plant material was good enough for the experiment to be conducted. However, two of the years have been rather harsh to the material, with a lot of autumn rains. Both winters of 2012 and 2013 were hard with e.g. minus degrees and frost on bare soil in 2012, especially in Alnarp. The field trials in Krusenberg showed the worst results mainly due to bad drainage leading to flooding and remaining water on the fields for long periods of the season.

Growth rhythm
The spring cereals had a rapid development during the spring and in the middle of May the spring rye was around 50 cm. The rest of the spring cereals were around 20-25 cm. During the four following weeks, the spring cereals became more than 100 cm tall and the Våremmer, vårspelt, and black oats varieties Klock and Engelbrekt ended up being 140 cm. The spring barley varieties ended up being 80 cm tall.

The winter rye was 90 cm tall in middle of May and continued to grow around 100 cm during the following four weeks. The rest of the winter cereals were around 30-40 cm in middle of May and most of them reached their maximum length two weeks later than the winter rye. Svartemmer and lantvete Halland ended up being 160 cm, while many of the other winter cereals ended up on around 140 cm. The most modern variety Ure became 105 cm tall.

Resistance towards weeds
In general, the spring and winter rye has the highest resistance towards weeds, mainly because of their early plant development and height. Also, barley showed high resistance towards weeds. Oats has in general a good resistance towards weeds although when the oats is attacked by crow type of birds and/or insects, weeds have higher opportunities to take over the space in the plantings. Wheat has in general lower resistance towards weeds although the older varieties are competitive because of their long straws.

All varieties in the field trials in Alnarp were more or less free from weeds, due to high plant density as a result of coverage of the plots with a cloth after sowing to protect against crows eating the oats seeds.

Also the other field trials were in general low in weeds densities, although as soon as there was lower plant density in any plot, resulting in bare soil or uneven plant height and development, there was an increase in weed, meaning that the best way to protect against weeds was to secure an even and well developed stand of the cereal.

Resistance towards diseases
In general there was low level of diseases in the investigated material. This can be explained by three main reasons. The trials hold a diverse set of plant material with a range of various genes, thereby protecting the material from being attacked by diseases. Variety mixtures as well as variations in what are grown in an area or region is known to protect against diseases. The second protection is the lack of very dense sowing in the experiment. Dense and short crops are known to increase the disease prevalence. The third reason for the lack of diseases in these field experiments might be the rather long distance between the flag leaf and the spike. For the plant material in the present field experiment, most of them were found to have a longer distance between the flag leaf and the spike than is normally found in more modern varieties. The reason for this is that the present plant material is taller than more modern plant

materials. It is know that a short distance between the flag leaf and the spike leads to increased disease levels in cereals.

In 2012, there were high levels of yellow rust in Skåne, which clearly showed variation in yellow rust resistance in the cereals used in the present study.

Thousand kernel number volume weight and protein content

As well thousand kernel number as volume weight and protein content varied depending on year, locality and variety. Thousand kernel number and volume weight is primarily related to how large space there is available for the grain in the spike and how well filled the grains are. All types of stresses, e.g heat and drought stress, diseases and pests attacks, leads to less filled grains in the crop. Thus, as soon as there is variation in space (mainly genotype determined) and stresses due to weather and abundance of insects and pests, it will lead to changes in thousand kernel number and volume weight.

Protein content is known to be genetically determined by a number of genes but also influenced by a number of stresses and environmental factors. Thus, yield influences the protein content as do biomass during the plant development and sizes of the grains. This means that a variation in protein content is always expected in field grown experiments. In the present experiment, the most obvious background for variation in protein content, was the negative correlation between yield and protein content, thereby resulting in highest protein content in the plant material grown in localities and years with problematic growing conditions i.e. bad drainage resulting in poor yield. Important when evaluating protein content is to try to understand whether there is interesting findings related to nutrition and baking (end-use qualities). Therefore, we are further evaluating the present plant material in follow-up projects to the hereby reported project as related to protein nutrition and composition as well as for baking qualities.

Essential minerals

Within the present reported project, only a small fraction of the present plant material has been evaluated for essential mineral, the reason for that is; lack of funding within the present project for the analyses and the fact that the plant material has to be produced before the analyses can be carried out. The full set of material is at present analyzed for essential minerals within a follow-up project funded by Ekhaga stiftelsen and we will have the results available during late spring 2015.

The limited fraction of the material that has been analyzed during the present project shows variation between localities and varieties for the analyzed minerals. For most of the minerals, highest contents were found at Ekhaga although the Lövsta material showed highest values for Magnesium and Cupper in spring cereals. High values of essential minerals were especially seen in Svartemmer, speltvete Gotland and borstvete Gotland among the winter cereals and våremmer and vårspelt were among the most interesting spring cereals. However, a much fuller picture, together with relations to growing environments will be available within a year.

Bioactive compounds and protein characteristics

Bioactive compounds and protein characteristics have not been analyzed in the present project due to lack of funding within the present project for the analyses and the fact that the plant material has to be produced before the analyses can be carried out. These analyses are therefore planned for 2016 within follow-up projects.

Publications from the project

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Hussain A, Larsson H, Kuktaite R, Prieto-Linde ML, Johansson E (2012) Towards the understanding of bread-making quality in organically grown wheat: Dough mixing behaviour, protein polymerisation and structural properties. J Cereal Sci 56:659-666.

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Popular presentations of the results

A substantial number of oral presentations by Hans Larsson for organic growers, and organic interested audiences of the results from this project and others. We are planning to produce a) a fact sheet from this project and a list of varieties with various qualities. However, those two formal popular publications will be finalized after the mineral analyses have been finalized for a more substantial number of the material.

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